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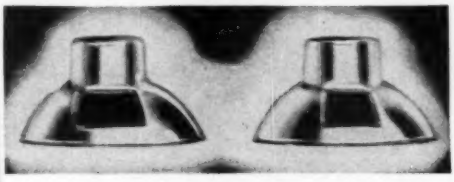

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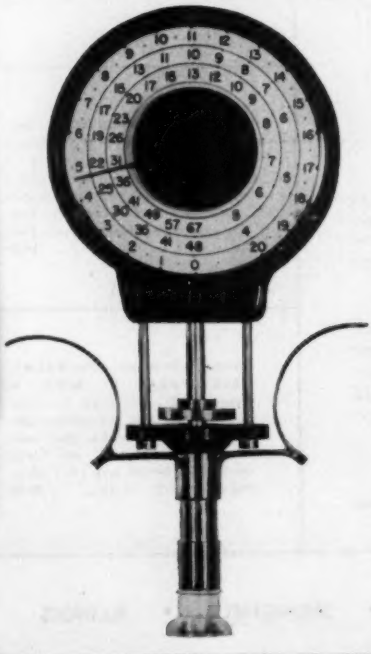

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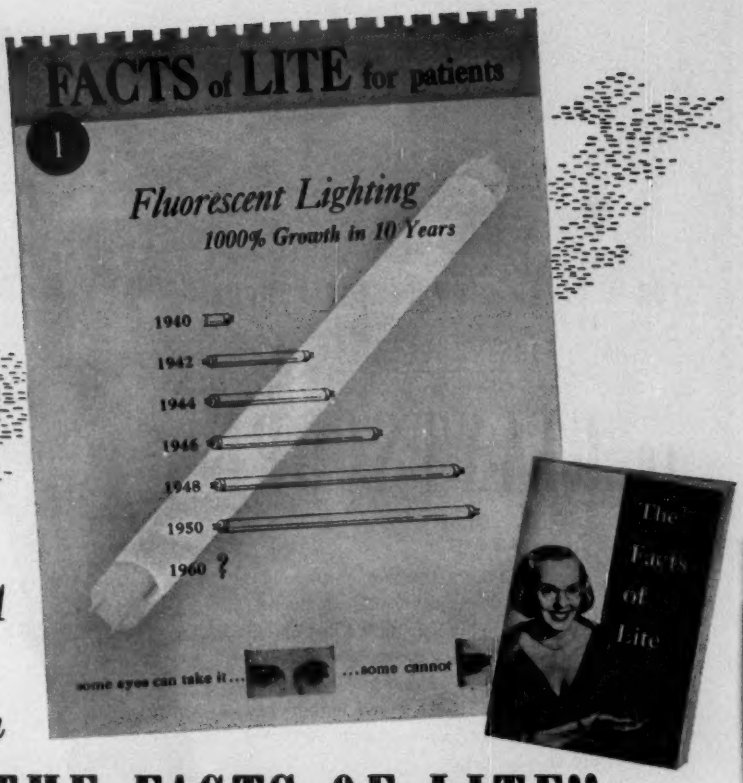

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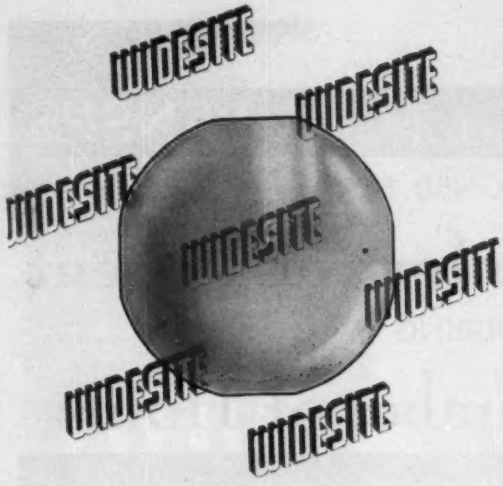

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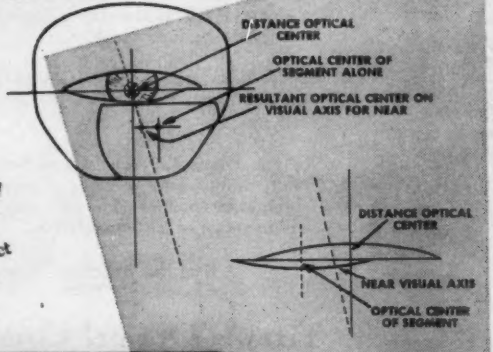
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RELATION OF DIPLOPIA TO BINOCULAR VISION IN CONCOMITANT STRABISMUS

ADOLPH POSNER, M.D.
AND
ABRAHAM SCHLOSSMAN, M.D.
NEW YORK

POSTOPERATIVE diplopia is usually regarded as a good prognostic sign because it presumably indicates an attempt at resumption of binocular function. Nevertheless, it can become, at times, a troublesome complication in the management of a case of strabismus. This problem has occupied the attention of ophthalmologists ever since von Graefe [1] wrote his monograph on postoperative diplopia in strabismus. In von Graefe's day, when the operation for strabismus consisted in tenotomy, the problem assumed greater importance because of the relative frequency of overcorrection. An additional factor may have been the tendency of surgeons to refrain from operating until the patient reached adulthood. With modern surgical techniques, postoperative diplopia, sufficient to become obtrusive, has become less frequent; but when it does occur it constitutes a serious problem both for the patient and for the ophthalmologist.

For clinical purposes, postoperative diplopia in concomitant strabismus may be classified as follows:

1. Diplopia occurring in cases with normal retinal correspondence. In these cases there may or may not be a coexistent facultative abnormal retinal correspondence.

A. In cases in which the strabismus was undercorrected. This is often associated with hypertropia.

B. In cases in which the strabismus was overcorrected. This is usually the severest and most intractable type of diplopia.

2. Diplopia occurring in cases with abnormal retinal correspondence.

A. Mild paradoxical diplopia. This type occurs frequently after operation and is usually self limited.

B. Severe paradoxical diplopia and triplopia (or monocular diplopia [Bielschowsky [2]]); this occurs in the presence of eccentric fixation of the squinting eye. Cases of this type are extremely rare.

Among the cases of postoperative diplopia, those belonging to type 1 B have occupied our attention, not only because of their clinical importance, but also because they offer an ideal experimental setup for the study of the physiologic mechanisms

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From the Department of Ophthalmology, Montefiore Hospital for Chronic Diseases.

1. von Graefe, A.: Beiträge zur Physiologie und Pathologie der schiefen Augenmuskeln, von Graefes Arch. Ophth. **1**:82-120, 1854.

2. Bielschowsky, A.: Über monokuläre Diplopie ohne physikalische Grundlage nebst Bemerkungen über das Sehen Schielender, von Graefes Arch. Ophth. **46**:143-183, 1898.

involved in binocular vision. We have observed 10 cases of this type. Since the clinical picture is essentially similar in all the cases, only two histories will be presented. The first illustrates the development of postoperative diplopia in a patient with convergent strabismus, while the second is one of divergent strabismus. From these two examples, it will be apparent that the same physiologic principles apply in both types of squint.

REPORT OF CASES

CASE 1.—Miss R. B., aged 20, had had convergent strabismus since she was 2 years old. In 1947, another ophthalmologist had found an alternating esotropia of 15 to 20 Δ and had performed a recession of the right medial rectus and a resection of the right lateral rectus muscle. Since that time the patient had constant double vision, more disturbing on distant gaze. Her vision could be improved to 15/15 in each eye with a correction of + 1.75 ax 105 for the right eye and + 0.50 ax 100 for the left eye. The eyes were cosmetically parallel, and motility appeared normal. She preferred to fix with the left eye. With the screen and prism test, there was an exotropia of 8 Δ for distance and near. Normal retinal correspondence was present. There was spontaneous crossed diplopia with approximately the same separation of images in all the fields. When the exotropia was neutralized with 8 Δ (base in), the diplopia disappeared. When the prism power (base in) was further increased, no spontaneous diplopia was elicited, even though it could be shown by means of the screen test that the eyes were in a position of relative convergence. An operation was suggested as the only procedure which promised to relieve the diplopia.

On April 19, 1949, the right medial rectus was detached from the globe and was sutured to its original insertion. On June 1, 1949, the patient experienced no spontaneous diplopia. Without glasses, there were present a residual esophoria of 2 Δ for near and an exophoria of 2 Δ for distance. When wearing her glasses, she complained of diplopia for distance, but not for near. Under these conditions, she showed a slight exotropia for distance and orthophoria for near. She was, therefore, advised to use her glasses for reading only.

CASE 2.—Miss E. S., aged 31, was examined for the first time at the Montefiore Hospital on Sept. 15, 1948. Her eyes had been divergent since infancy. Vision was 15/15 in each eye. Under homatropine cycloplegia, she accepted + 1.00 sph. for each eye. Her strabismus measured approximately 40 Δ for distance and near, and she could fix equally well with either eye. Retinal correspondence was normal. A diagnosis of alternating divergent strabismus was made.

On Oct. 11, 1948, a 5 mm. recession of the right lateral rectus and an 8 mm. resection of the right medial rectus muscle were performed. After the operation, the patient complained of intolerable diplopia. While the eyes were cosmetically straight, examination revealed a slight esotropia. In the course of time, the diplopia became less disturbing, except on right lateral gaze.

When the patient was last seen, on March 1, 1950, there was spontaneous homonymous diplopia on right lateral gaze, beyond 15 degrees from the median plane. In the primary position, with the red glass, there was crossed diplopia of 2 Δ for near. This exophoria was found also with the screen test. On right lateral gaze, however, a varying amount of esotropia associated with spontaneous homonymous diplopia was present for distance and near. When this esotropia was corrected or overcorrected by prism base out, the diplopia was abolished.

On left lateral gaze, a slight exotropia was noted in the screen test. While the patient was not aware of spontaneous diplopia, the red glass test revealed the presence of crossed diplopia. It is noteworthy that diplopia could be elicited in this position even without a red glass by overcorrecting the exotropia with prism base in, thus simulating an esotropia. On the other hand, with the use of prism base out, spontaneous diplopia could not be evidenced. This held true even when a vertical deviation was introduced at the same time by adding prism base up or base down.

The patient experienced a feeling of strain on using her eyes even in the field of binocular single vision. This may be attributed to the fact that a certain amount of incomitance was produced by the operation.

COMMENT

The essential features presented by these cases are as follows:

1. Both patients had good vision in each eye.

2. The strabismus had existed since early childhood and was not corrected until adult life.

3. Both patients had normal retinal correspondence.

4. These patients had never experienced diplopia until after the surgical intervention.

5. Even though the cosmetic result in each case was excellent, both patients showed a slight overcorrection.

6. In one patient (R. B.) the diplopia following the first operation was so disturbing that she eagerly submitted to a second operation, which gave promise of relief from her diplopia.

In these cases, it is obvious that the diplopia developed as an aftermath of the surgical intervention. Originally, the patients were able to suppress one of the images. After correction, however, binocular vision involved areas of the retina which were not capable of suppression. In the case of convergent strabismus, the patient was able to suppress images falling on the nasal portion of the retina. After overcorrection the extrafoveal image fell on the temporal portion. Since this part of the retina had not previously been exposed to conditions necessitating suppression, the patient was now unable to suppress and hence experienced crossed diplopia. By means of the red glass test, diplopia could be elicited even in those areas in which it was not spontaneous. This is additional evidence that in these cases there is a quantitative difference between the nasal and the temporal portion of the retina with regard to their ability to suppress retinal images.

In the case of divergent strabismus, it was the temporal portion of the retina which had originally developed the ability to suppress. After surgical intervention, the position of the eyes was so altered in certain fields of gaze that the nasal part of the retina of the nonfixing eye received the extrafoveal image. For this reason, the patient experienced spontaneous homonymous diplopia.

Patients who are subject to this type of postoperative diplopia have either normal or facultative anomalous retinal correspondence. In the presence of obligatory abnormal retinal correspondence, one frequently observes postoperatively a paradoxical diplopia. This diplopia is generally transient; rarely, it may remain constant.[2] Since abnormal retinal correspondence represents an adjustment of the sensory mechanisms to an abnormal situation, it is easy to understand how such a person can subsequently make a new adjustment to conditions obtaining after surgical correction of the squint.

In children, too, the phenomenon of postoperative diplopia is often observed, but it is not as important or as acute as in adults. In the course of time, the child can make the necessary adjustments. Careful inquiry revealed that many patients with concomitant strabismus experience spontaneous diplopia at one time or another. These observations led us to investigate the possibility of inducing diplopia in such cases without the use of a red glass. In cases of alternating convergent and divergent strabismus and in those cases of monocular strabismus in which suppression is not too profound, we made the following observations.

1. If, by the use of prisms, the retinal image is shifted to that portion of the retina of the squinting eye on which it does not normally fall, the patient may experience diplopia. In a case of convergent strabismus, the image of the squinting eye falls habitually on the nasal half of the retina. If a sufficient amount of prism base out is used to overcorrect the deviation, thus causing the image to fall on the temporal portion of the retina, the patient experiences crossed diplopia. Similarly, in a case of divergent strabismus, prism base in can produce homonymous diplopia if it is of sufficient strength to overcorrect the strabismus.

2. In a case of convergent strabismus, if the fixation object can be brought nearer than the point of intersection of the visual axes, the patient frequently experiences crossed diplopia.

3. In many cases of convergent strabismus, it is possible to elicit crossed physiologic diplopia, while homonymous physiologic diplopia cannot be as readily produced.

THEORETICAL CONSIDERATIONS

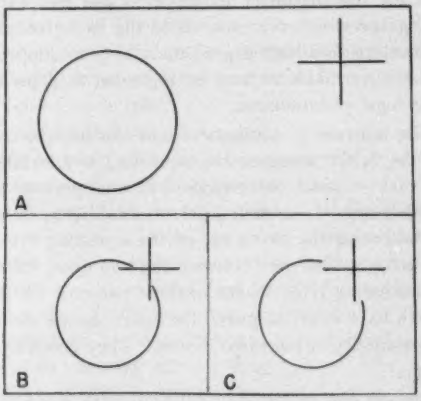
These observations demonstrate that the patient has learned to suppress those parts of the retina on which the images habitually fall, but that he has not learned to suppress the parts of the retina on which the images do not habitually fall. He is, therefore, theoretically liable to experience postoperative diplopia should an overcorrection result from the operation. That a larger percentage of patients do not suffer from permanent postoperative diplopia is due to the fact that in most cases the other parts of the retina acquire the ability to suppress. This is particularly true of children, since their nervous system is in a relatively plastic state. The ability of the organism to adapt itself to altered conditions is not entirely lacking, even in the adult. Some patients with paralytic strabismus may develop suppression when the strabismus becomes comitant.

Suppresion is a physiologic phenomenon present in all normal persons under normal conditions of binocular vision, but to a varying extent. On it depends our ability to see binocularly without being conscious of physiologic diplopia. This can be demonstrated in a stereoscope. If two dissimilar images are presented to the two eyes, a portion of one image will be suppressed, to make room for the other image. If a small cross is seen with the right eye and a large circle with the left eye, so that the cross intersects the circle, a segment of the circle will be suppressed. The arc of the circle which appears to be missing is that portion enclosed between the limbs of the cross and a varying section to either side of the cross. The extent to which the circle disappears, both as regards the size of the segment and the intensity of suppression, depends on the relative dominance of the two eyes. If the cross is seen with the nondominant eye, while the dominant eye sees the circle, a smaller portion of the circle is suppressed. If, on the other hand, the cross corresponds to the dominant eye, the suppression will be greater.

This phenomenon is intimately linked with the broader concept of gestalt psychology. At this point, it is only necessary to mention that in this experiment the cross represents the figure, while the circle, being larger, represents both figure and background. The background for the cross, seen by the right eye, is a uniform white surface, which does not obtrude itself as strongly into consciousness. When the two images are superimposed, the part of the circle which corresponds in position to

the cross disappears, while the remainder, which assumes the role of the background, does not have to be suppressed. At the same time, the cross, which represents the figure, carries with it a variable amount of its white background. The role played by dominance is manifested by the fact that the dominant eye gives the stronger representation of the figure in consciousness and, therefore, exerts a greater suppressing influence on the other eye, so that both the area and the intensity of suppression are greater in the nondominant than in the dominant eye.

This phenomenon of retinal rivalry is most pronounced when the images presented to the two eyes are dissimilar. It is possible to demonstrate, by appropriate methods, that the degree of dissimilarity can be reduced in so continuous a manner that no sharp end point can be detected where dissimilarity ends and similarity begins. Under natural conditions of binocular vision, there are two types of binocular imagery. Within certain limits, dissimilar images are fused to give rise to stereopsis. At the same time, some of the dissimilar images which would tend to give



Effect of figure and ground on suppression. *A*, stereoscopic card in which cross represents the figure and circle represents the ground. *B*, fused image of *A* in which cross is seen with nondominant eye. *C*, fused image of *A* in which cross is seen with dominant eye.

Note that a larger arc of the circle is missing in *C* than in *B*. This corresponds to the greater degree of suppression when the cross is seen with the dominant eye.

rise to physiologic diplopia are of necessity suppressed. Since there is a continuous flux in our interpretation of spatial relationships with regard to figure and ground, the images which at one moment were suppressed change places with those images which at the same moment were fused. Thus, it is evident that the processes characteristic of retinal rivalry and suppression are encountered in normal binocular vision. Retinal rivalry has occupied the attention of various observers since Wheatstone [3] first demonstrated the principles of stereoscopic vision. Johannes Müller [4] recognized the importance of retinal rivalry in binocular luster and other binocular

3. Wheatstone, C.: Contributions to the Physiology of Vision: On Some Remarkable, and Hitherto Unobserved, Phenomena of Binocular Vision, Phil. Tr. London, pp. 371-394, 1838.

4. Müller, J.: Zur vergleichenden Physiologie des Gesichtssinnes des Menschen und der Thiere, nebst einem Versuch über die Bewegungen der Augen und über den menschlichen Blick, Leipzig, C. Cnobloch, 1826, pp. 79 and 194-204.

functions. More recently, Verhoeff [5] presented a hypothesis explaining stereoscopic vision by retinal rivalry, or what he calls "replacement."

We feel that the pattern of retinal rivalry associated with binocular vision is governed by the principles enunciated in gestalt psychology. Whichever object is fixed at the moment becomes the dominating figure in binocular vision, while the remainder serves as the background. The figure may change from moment to moment, so that what was previously the figure can later recede into the background. The figure determines the attention value. *Thus, binocular vision becomes a kinetic concept in accordance with which there is a continuous interplay between figure and ground on the psychologic level and between dominance and suppression on the physiologic level.*

In other fields of medicine, we recognize that a pathologic condition may be regarded as an aberration or an exaggeration of some normal physiologic process. This principle applies equally in the case of binocular vision in strabismus. If it becomes important for the organism to suppress one eye habitually, that retinal area of the nonfixing eye which corresponds to the background for the figure seen by the fixing eye develops to a high degree the ability to suppress. Therefore, suppression associated with strabismus may be regarded as a pathologic exaggeration of the normal physiologic phenomenon.

Since suppression is easier of attainment and can become more complete in the nondominant eye, the latter becomes the squinting eye, while the dominant eye becomes the fixing eye. A small percentage of normal persons show no demonstrable dominance of either eye. If in such a person strabismus develops, either eye has an equal chance of becoming the fixing eye or the squinting eye. If the suppression and the dominance actually alternate between the two eyes, the resultant strabismus is apt to be of the alternating type. Some of these patients who have had alternating strabismus since birth have never acquired the ability to use their eyes together and, therefore, have no possibility of binocular vision. They probably will not experience postoperative diplopia.

In the other group, who have the ability to use their eyes together, alternating suppression of the squinting eye develops and a facultative anomalous retinal correspondence may appear. Some of these patients have occasional fleeting diplopia, while some who do not have diplopia may acquire diplopia later in life by becoming conscious or aware, through some circumstance, of the false image. These patients, when they are overcorrected by operation, especially if the operation is performed late in life, will have diplopia, which will be either temporary or permanent. It is fortunate for the surgeon that nature is on his side and that those patients who retain permanent diplopia are not common.

In an attempt to determine the role of the blindspot in aiding the squinting eye to suppress the false image, we have studied several cases of convergent strabismus of about 15 degrees, By means of vertical prisms, the false images were displaced away from the horizontal meridian. Even under these conditions, diplopia did not occur until the image had also been shifted by base-out prisms to the opposite half of the retina, when crossed diplopia appeared.

5. Verhoeff, F. H.: A New Theory of Binocular Vision, Arch. Ophth. **13**:151-175 (Feb.) 1935.

CENTRAL VERSUS PERIPHERAL VISION

Ocular dominance is a term which describes the result obtained by a special type of test, namely, the sighting test. Thus, the word "dominance" refers only to central vision, and not to vision of the eye as a whole. It would appear from clinical observations that dominance plays at best a minor role in peripheral vision.

Since retinal rivalry is influenced to a high degree by ocular dominance, one should expect the most pronounced effects to occur in those areas of the retina which are used in fixation. Thus, when suppression develops, it tends to involve more or less limited areas of the retina. The remainder of the retina may retain its relatively normal function, namely, the ability to produce binocular vision in conjunction with the corresponding area of the other eye. Thus, many strabismic patients have either peripheral fusion or, at least, the ability to acquire peripheral fusion when the eyes are placed in the appropriate relation to each other. To revert again for a moment to the principles of gestalt psychology, this relative stability of peripheral fusion can be explained by assuming that it is easy to fuse the background because the latter does not involve either ocular dominance or the attention mechanism and there is, therefore, relatively little need for suppression; neither are the peripheral images as distinct or as obtrusive, even when they do not completely correspond to each other.

Central and peripheral vision may be compared also from an evolutionary point of view. The function of peripheral vision being orientation, it is a more primitive function than the more recently acquired central vision, which has for its purpose the discrimination of objects. For the organism as a whole, the function of orientation is the more important one. In the periphery of the field, the phenomenon of binocular rivalry is not so fundamental a problem for the organism as to preclude the possibility of binocular cooperation. For this reason, peripheral fusion is more stable and often remains intact even after suppression of the central area has developed to a relatively high degree. This area of peripheral fusion may, therefore, be used by the patient to restore binocular single vision either with or without the aid of orthoptic training or surgery. We have seen cases in which binocular single vision developed spontaneously several years after the surgical correction of the squint, even though it had not been present immediately after the operation.

It is generally taken for granted that diplopia in paralytic squint is dependent solely on the factor of incomitance. While this is probably true in the average case, there is some reason to question the universal validity of this assumption. There are cases of incomitance beginning at birth or early in life in which binocular single vision is present in a portion of the field of fixation, while suppression occurs in the remainder of the field. Duane's syndrome, overaction of the inferior oblique, paresis of the superior rectus and paresis of the superior oblique are examples of this type.

CONCLUSIONS

1. Diplopia in strabismus can be explained on principles derived from normal physiology.

2. Some of the phenomena observed in normal binocular vision are retinal rivalry, ocular dominance, regional suppression and fusion.

3. In squint, ocular dominance determines the fixing eye, and also the degree and extent of suppression.

4. If conditions are so altered by surgical correction that the images fall on areas of the retina which have not developed the ability to suppress, diplopia results.

5. Peripheral fusion, being phylogenetically more primitive and less influenced by ocular dominance, is more stable than central fusion.

6. When peripheral vision still shows a normal binocular relationship, it may be utilized as the starting point for orthoptic training. An attempt should be made to build up central binocular relationships within the framework of this peripheral fusion to the maximum capacity of the patient. This will vary with each case.

7. Since the elements of binocular vision can be traced to the more general neurologic and psychologic phenomena which are associated with the gestalt concept, binocular vision may be interpreted as a special application of the gestalt concept.

667 Madison Avenue.

OCULAR COMPLICATIONS ENCOUNTERED IN INTRACRANIAL ARTERIOGRAPHY

HAROLD F. FALLS, M.D.
ROBERT C. BASSETT, M.D.
AND
AUSTIN E. LAMBERTS, M.D.
ANN ARBOR, MICH.

INTRACRANIAL angiography,[1] the roentgenographic examination of the skull following the perfusion of intracranial vessels, has become an established routine in the diagnostic armamentarium of the neurosurgeon. The procedure provides an excellent means of obtaining diagnostic information in cases of suspected intracranial aneurysm and anomalies of intracranial vasculature and in selected cases of arterial occlusion and expanding cerebral lesions.

That angiography is not without danger is freely admitted by most neurosurgeons. Complications, such as pain, arterial spasm, allergic phenomena, thrombosis, emboli, convulsions, hemiplegia, exacerbation of existing symptoms, and even death, may be encountered. It is of interest that, except for an occasional reference to the eye, there is a remarkable lack of reported ocular complications. Weekers,[2] however, has reported a case of occlusion of the right temporal retinal artery following injection of the right internal carotid artery with 20 cc. of iodopyracet solution ("umbradil"). The patient also presented a convulsive seizure and left hemiplegia.

One of us noted that patients who had had intracranial angiography exhibited facial and conjunctival petechiae postoperatively on the homolateral side. This observation instigated the present study. It is our intent to report the frequency and type of ocular complications encountered in the patients undergoing intracranial angiography at the University of Michigan Hospital.

TECHNIQUE

In this study the ophthalmologist was consulted the day before the arteriographic procedure in order that a preoperative ophthalmological survey of the patient could be performed. This examination was repeated as soon as possible on completion of the angiographic study and again on the second postoperative day.

1. List, C. F., and Hodges, F. J.: Intracranial Angiography: Diagnosis of Vascular Lesions, J. Neurosurg. **3**:25, 1946.

2. Weekers, R.: Accident vasculaire rétinien aprés artériographie cérébrale, Ann. ocul. **182**:926, 1949.

The following surgical technique of intracranial angiography was employed during the period of the study (July 1949 to December 1950) by the department of neurosurgery.[1] The bifurcation of the common carotid artery was exposed by an incision parallel to the sternocleidomastoid muscle. Untoward sytemic reactions from the carotid sinus reflex were avoided by local injection of procaine. The external carotid artery was strangulated by means of a rubber strip. The needle puncture was made in the common carotid artery just proximal to the bifurcation. Ordinarily, three injections were made—two to obtain stereoscopic lateral views and the third for a single anteroposterior projection. The radiopaque material (thorotrast® or iodopyracet injection U. S. P. [diodrast®]) was forced into the artery as rapidly as possible. In an attempt to prevent clotting on the completion of the administration of the contrast medium, an injection of 20 cc. of Ringer's solution was employed to flush out the tubing, needle and artery.

OBSERVATIONS

Petechial Hemorrhages.—The table presents the position and frequency of petechial hemorrhages observed in and about the homolateral eye and adnexa in 80 consecutive arteriographies. Conjunctival petechiae, especially in the fornices, were almost a constant feature (81.3 per cent) of intracranial arteriography. They could be visualized almost immediately on completion of the perfusion of the contrast medium in some cases. In other patients the hemorrhages were not visualized

Petechial Hemorrhages Observed in Eighty Consecutive Patients

Position	Number of Patients	Percentage
Skin	35	43.8
Conjunctiva	65	81.3
Retina	20	25.00
Skin, conjunctiva, and retina	13	16.3
Combination of any two	39	48.7

until 30 to 90 minutes after operation. While it is not possible to present adequate proof, there is a suggestion of some correlation between the frequency and severity of the petechiae and the amount of the contrast medium injected.

The majority of the retinal hemorrhages were round, granular and, in a few cases, preretinal. While an occasional hemorrhage was seen in the retinal periphery, the larger number was confined to the posterior pole. Many of the hemorrhages presented white centers, and in many cases cotton-wool exudates were also present.

OPTIC NEURITIS

Severe optic neuritis was encountered in one patient, with eventual complete loss of vision. Temporary visual loss (10 to 30 minutes) was observed in two patients, with subsequent return to normal. The visual loss in these patients was interpreted to be vasospastic in nature, although neither patient's fundus was studied during the period of visual loss.

Pupil.—The homolateral pupil was temporarily dilated in five patients, with return to normal within three to 24 hours.

Pain.—Pain in and about the eye was a complaint of two patients who received the iodopyracet injection.

Death.—One death, secondary to thrombosis of the internal carotid artery, followed the intracranial angiographic procedure.

No Sequelae.—No complications could be demonstrated in 11 patients, or 13.8 per cent. Stated conversely, ocular complications were encountered in 86.3 per cent of the patients who had intracranial arteriography.

NEUROLOGICAL AND SYSTEMIC COMPLICATIONS

The records of 457 patients undergoing intracranial arteriography (1941-1950) were reviewed for the occurrence of sequelae of a serious neurological nature. Four patients became seriously comatose; six had hemiplegia or hemiparesis, and six experienced convulsions. On introduction of the needle, spasm of the carotid artery was met twice.

COMMENT

It is impossible to state the cause of the ocular complications which have been observed to follow intracranial angiography. The presence of petechiae in the skin of the eyelid, the conjunctiva and the retina suggests vascular change, which, undoubtedly, may result from numerous factors. Elwyn [3] interprets Ricker to the effect that constriction of the arterioles produces slowed and irregular circulation, effecting peripheral dilatation of the affected artery, capillaries and veins—so-called peristatic hyperemia. Characteristic of this form is the increased fluid passage through the capillary walls, producing cotton-wool exudates and, when severer (prestatic hyperemia), permitting hemorrage by diapedesis. "The peristatic and prestatic forms of hyperemia are of great importance in that they explain the production of edema and retinal hemorrhages."

Of the many factors to be considered, the contrast mediums (thorotrast,* 25 per cent, and iodopyracet injection U. S. P., 35 per cent) may be looked on with suspicion, for certainly there is not yet available a truly satisfactory contrast medium for intracranial angiography. Iodopyracet is promptly and completely excreted, but local irritation and occasional severe convulsions may accompany its use. Iodopyracet, in addition, carries the serious threat of allergic reactions. Pendergrass and others,[4] after a fatal reaction to iodopyracet, surveyed the urological field and encountered 26 unreported fatal reactions, in addition to 11 previously reported fatalities. Thorotrast,* 25 per cent thorium dioxide in colloidal suspension, has been reported to have effected occlusion [5] of small cerebral vessels, with resultant encephalomalacia, and even death.[5] The colloidal material may in itself produce thrombosis, or even emboli. The potentiality of long-delayed radiation damage must always be kept in mind. Irritation of the carotid sinus during the arteriographic procedure is a strong possibility in predisposed persons, despite local anesthesia. Cerebral vasomotor phenomena, arterial spasm and its sequelae may thus occur. Air emboli, a result of faulty technique, must always be kept in mind. Allergic and toxic vasomotor reaction may frequently occur in sensitized persons from any intravenous perfusion.

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3. Elwyn, H.: Diseases of the Retina, Philadelphia, The Blakiston Company, 1947.

4. Pendergrass, E. P., and others: Survey of Deaths and Unfavorable Sequelae Following the Administration of Contrast Media, Am. J. Roentgenol. **48**:741, 1942.

5. Pendergrass and others.[4] Northfield, D. W. C.: Observations on Clinical Indications for Cerebral Arteriography, Lisboa méd. **14**:861, 1937. Ekström, G., and Lindgren, A. G. H.: Cerebral Injuries After Arteriography of the Brain with Thorotrast, Acta chir. scandinav. **82**:291, 1939.

Personal communications from numerous neurosurgeons have revealed that many have failed to observe the ocular complications discussed in this paper. It is possible that they have been overlooked. On the other hand, it is possible that our technique may be the contributory factor. Investigation now in progress may afford us the answer.

SUMMARY

Eighty consecutive cases of intracranial angiography have been reviewed for evidence of ocular complications. Petechial hemorrhages of the skin of the eyelids, of the palpebral and bulbar conjunctiva and of the retina were demonstrated. Pupillary dilatation, optic neuritis, angiospasm of retinal vessels and blindness were also encountered. The cause of these complications is not known, but they undoubtedly result from vascular change secondary to allergic, toxic or physical phenomena.

201 South Main Street (Dr. Falls).

OPHTHALMOSCOPIC FINDINGS IN NORMAL PREMATURE INFANTS

GEORGE S. TYNER, M.D.
PHILADELPHIA

A SEARCH of the literature has revealed no detailed description of the normal eyeground in the premature infant. This paper presents observations recorded during the routine examination of premature infants in the nursery of the Hospital of the University of Pennsylvania as part of the program for early recognition and treatment of retrolental fibroplasia. During the past 18 months my colleagues and I examined 200 infants. Certain differences were noted between the fundi of the normal premature infants and the fundi of normal older children. Some of these differences are difficult to distinguish from the earliest changes of retrolental fibroplasia, first described by Owens and Owens.[1] A description of our findings seems of some value because of the importance of distinguishing the early changes of retrolental fibroplasia from the normal.

In our experience, normal premature infants may show pallor of the peripheral portion of the fundus, large retinal veins, hazy ocular media, a tapetum-like reflex in the fundus, retinal hemorrhages and pale optic nerve heads. Attention was recently called to hemorrhages in the fundi of newborn infants by Chace and associates.[2] Pallor of the optic disks has long been recognized as a normal finding in infants.

1. Pallor of the peripheral portion of the fundus. In our experience, the periphery of the retina is always paler than the posterior pole. As the periphery of the fundus is viewed, the homogeneous red color of the fundus changes to pale gray. Often the choroidal vascular pattern is plainly visible, as in albinos. As the periphery is approached, this pattern can no longer be seen but gives way to the flat, pale gray color. Retinal vessels are plainly visible over the area.

No explanation for this pallor is evident. It is possible that in the premature infant there is incomplete differentiation or development of retinal and choroidal pigment. It is known that the central region of the retina continues to differentiate until at least 16 weeks after full term birth.[3] Macular development and pigmentation of both the retina and the choroid are closely related.[4] This pallor has been

From the Department of Ophthalmology, Hospital of the University of Pennsylvania.

1. Owens, W. D., and Owens, E. U.: Retrolental Fibroplasia in Premature Infants, Am. J. Ophth. **32**:1 (Jan.), 1631 (Dec.) 1949.

2. Chace, R. R.; Merritt, K. K., and Bellows, M.: Ocular Findings in the Newborn Infant: A Preliminary Report, Arch. Ophth. **44**:236 (Aug.) 1950.

3. Duke-Elder, W. S.: Text-Book of Ophthalmology, vol. 1, St. Louis, C. V. Mosby Company, 1933, pp. 332-333.

4. Mann, I.: Developmental Abnormalities of the Eye, London, Cambridge University Press, 1937, pp. 153-158.

noted for several months after birth. It has not been possible for us to follow many of the normal infants after they leave the hospital. We are therefore unable to say when the pallor disappears. We have not noted it after the macular reflex is seen ophthalmoscopically.

2. Large retinal veins. An arteriovenous ratio of 1:2 or 1:3 is, in our experience, a common finding in normal premature infants. We first became aware of this increased size of the veins while carrying on nutritional experiments on newborn dogs. Enlarged retinal veins were seen during the neonatal period in all our animals, including the controls. It became apparent after examining numerous premature infants that the retinal veins are frequently enlarged. It may be coincidence that many of these infants are anemic and that after the anemia has been corrected the veins appear more normal in size.

3. Hazy ocular media. Clouding of the vitreous is seen during the acute stage of retrolental fibroplasia. We have been misled by another cause of cloudy ocular media, which is so obvious that it may be overlooked. The corneas of these infants are covered by a mucus-like protective film, probably supplied by the conjunctival glands. True tearing is absent. Often, if this film is abundant, the fundus appears hazy. To obtain a clear view, it may be necessary forcefully to wipe the corneal surface with the upper lid or to irrigate the eye. Remnants of the anterior pupillary membrane are frequently seen, as well as of the hyaloid circulation, especially in the smaller infants.

4. Tapetum-like reflex in the fundus. We have often noted a glistening, greenish yellow reflex in the posterior pole in Negro and other dark pigmented infants. This tapetum-like reflex disappears as the child grows older. The cause is not obvious, but we have observed it so often that we consider it a normal variant.

5. Retinal hemorrhages. A few scattered retinal hemorrhages or an isolated large retinal hemorrhage is occasionally seen in premature infants with no apparent disease. Five per cent of the normal infants showed one or more retinal hemorrhages.

6. Iris color. It is a commonly accepted idea that the irides of newborn infants are blue. In this group of 200 infants, the irides were more commonly a nondescript slate or grayish brown color. Some showed dark brown irides.

SUMMARY

The eyes of 200 premature infants born at the Hospital of the University of Pennsylvania were examined in the nursery during the past 18 months. During the course of routine examinations certain differences were noted between the fundi of normal premature infants and the commonly accepted ophthalmoscopic picture described for normal fundi. These differences are hazy media; pallor of the peripheral retina; frequent occurrence of large retinal veins; a tapetum-like reflex, often seen in darker-skinned infants, and occasional retinal hemorrhages.

CONCLUSIONS

Hazy ocular media, enlarged retinal veins, pallor of the peripheral portion of the retina and retinal hemorrhages are seen in normal premature infants. It is important to differentiate these findings from the more pronounced changes seen in the acute stage of retrolental fibroplasia. Premature infants who show only

these conditions and in whom a normal adult type of fundus subsequently develops should not be considered as presenting retrolental fibroplasia which spontaneously regresses. It is possible that some of the confusion existing over the time of onset of retrolental fibroplasia is related to the lack of knowledge concerning the normal premature fundus.

NOTE.—After this paper had been sent in for publication, I noted a description of the normal optic fundus of infants and children by Walsh.[5] This description includes some of the findings presented in this paper, as well as others not mentioned.

5. Walsh, F. B.: Clinical Neuro-Ophthalmology, Baltimore, Williams & Wilkins Company, 1947, pp. 416-417.

SOME CONTEMPORARY CONCEPTS OF SCLERAL DISEASE

KENNETH C. SWAN, M.D.
PORTLAND, ORE.

IN THE preface to his "Manual of Diseases of the Eye," Dr. Charles H. May stated that he would endeavor to give the fundamental facts of ophthalmology.[1] The phenomenal popularity of his manual as a foundation text is adequate testimony that he succeeded; therefore, it seems only appropriate that this lecture presented in his memory should concern the fundamental aspect of some ophthalmologic subject. I have chosen to discuss the sclera because, in comparison with accumulated knowledge of the cornea and other ocular tissues, there is an almost amazing paucity of basic information on the sclera and its disease processes. Even in the most advanced treatises on ophthalmology only a few pages are devoted to this clinically important subject.

In the clinics and laboratories of the University of Oregon Medical School, we have been concerned for several years with various problems related to the sclera. Some concepts have necessarily evolved as data have been obtained. These data are based on studies which are still in progress and must be considered revisable. In presentation of these concepts, it is not my intention to review the literature or to discuss all aspects of controversial issues; rather, it is my hope to encourage discussion of our viewpoint and to interest others in doing research in this field.

The sclera is commonly spoken of as the fibrous outer coat of the eye; however, the term "fibrous" is a general one, which does not indicate the true physical nature of the sclera, and it is not specific enough to permit correlation of physiologic and disease processes in the sclera with those in other mesenchymal tissues. As compared with most other types of connective tissue, there is a relative paucity of cells in the sclera; rather, it is composed almost entirely of intercellular materials. Interlacing collagenous fibers, with only occasional fine elastic fibers, and an amorphous ground substance are the major components. This recognition of the sclera as a collagenous tissue is essential to an understanding of its physical properties, abnormalities, responses to injury and, particularly, relation to disease involving collagenous tissues in the skin, vessels, joints and other parts of the body.

There has been considerable confusion concerning the classification of scleral inflammations. In the strict sense inflammation is the response of tissue to injury. Thus reactions may be classified into several general groups in accordance with the type of tissue response. The sclera is primarily an intercellular tissue which has few

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From the Department of Ophthalmology, University of Oregon Medical School.

Charles H. May Memorial Lecture presented before the Section of Ophthalmology, New York Academy of Medicine, April 17, 1950.

1. May, C. H.: Manual of Diseases of the Eye, Baltimore, William Wood & Company, 1900.

blood vessels; consequently, proliferative response to injury does not occur to an appreciable degree except by invasion of cells from adjacent tissue. In some types of injury to areas where there are blood vessels exudative responses predominate, whereas in other types of injury the scleral reaction is primarily a physicochemical change, such as hyalinization; therefore, classification of scleral inflammation in accordance with the predominant tissue response is possible and provides a sound approach for investigating the scleral inflammation. Also, it has provided us with a more workable basis for clinical management than the time-honored methods of classifying scleritis on an anatomical basis, e. g., anterior scleritis, or on the basis of clinical description, e. g., brawny scleritis. An etiologic diagnosis is desirable, but there are many instances in which a specific causative factor cannot be determined. In these cases of scleritis of unknown cause an understanding of the tissue response is essential, because therapy and clinical management must be based on knowledge of the course of the process, its complication and sequelae.

Proliferative scleritis typically occurs as an excessive response to an acutely destructive injury, such as an operative incision or the focal destruction which accompanies the use of diathermy in operations for retinal separation. It is clinically significant that response of the sclera to such physical injury differs widely from that of the cornea.

The corneal stroma is normally in a state of relative detergescence; consequently, if a penetrating wound occurs through the cornea, the stromal fibers at the wound edges imbibe water from the aqueous and tears. This swelling may result in closure of even an appreciable defect. Both epithelium and endothelium tend to heal over the defect rapidly, and later stromal cells by proliferation participate in the sealing of the gap. Closure of penetrating corneal wounds is, therefore, by primary intention. Contraction of the wound and other complications of extensive cicatrization do not occur to an appreciable degree in a clean, uncomplicated injury to the cornea, such as an operative incision. In contrast, scleral fibers do not swell readily; rather, edges of a penetrating scleral wound may tend to retract. There are no epithelial or endothelial surfaces to bridge across the gap, and the stromal cells of the sclera participate little, if at all, in the healing of a wound. Healing by primary intention does not occur. Instead, the defect is filled in by the proliferation of mesenchymal tissue from the episclera and choroid. Repair of a scleral laceration is therefore comparable to healing of the dermis of the skin by secondary intention. There are an initial filling of the defect by fibroblastic tissue and, later, the laying down of collagen. This secondary type of healing of scleral wounds, as compared with that of corneal wounds, has a different clinical significance in the anterior than in the posterior segment. This subject is discussed in detail elsewhere, but a brief summary is pertinent to this report.[2]

The usual incision for cataract extraction is limbic or corneal and heals rapidly by primary intention. If the incision is behind the limbus and enters the anterior chamber deep in the angle, the repair of the wound often acquires the features of scleral, rather than corneal, healing. Complications may result because not only may the fibroblasts fill the wound but also, if there is a framework of lens material, fibrin or vitreous on which to proliferate, they may extend into the anterior

2. Swan, K. C.: Fibroplastic Ingrowth from Scleral Wounds, to be published.

chamber. If vitreous is in apposition with the wound, a typical clinical picture results which we have designated as fibroblastic ingrowth. Fibroblastic ingrowth into the anterior chamber has received little attention and therefore is frequently misdiagnosed as being epithelial in nature. This fact was established by studying specimens sent to our laboratory with the clinical diagnosis of epithelial ingrowth. Histologic study revealed that in an appreciable percentage of these cases of epithelial ingrowth reported to be cured with small doses of radiation the tissue was in reality fibroblastic. The differential diagnosis of epithelial and fibroblastic ingrowths therefore merits discussion.

Epithelial ingrowths characteristically have an irregularly rounded border, a smooth regular surface and are semitransparent. They tend to grow down the posterior surface of the cornea, to form cysts and to grow over or split the iris. In contrast, fibroblastic ingrowths seem to extend down the posterior surface of the

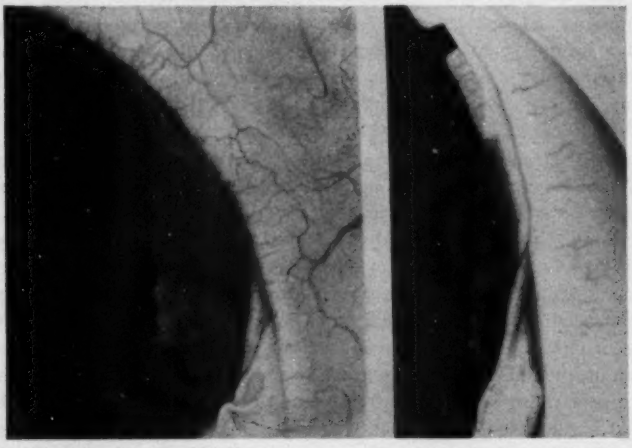


Fig. 1.—Fibroblastic ingrowth following cataract extraction. A sheet of fibroblastic tissue extends from the line of incision onto the face of the vitreous. (Slit lamp biomicroscopic [left] and gonioscopic [right] drawings by Lee Allan.)

cornea only in areas where the endothelium has been traumatized. Growth is characteristically on the surface or into the vitreous. The surface of a fibroblastic membrane is gray or white, and the interlacing meshwork of fine fibers gives it the appearance of woven cloth. The edges are frayed, with fine tonguelike strands running ahead. It can be differentiated from lens remnants by the absence of fluorescence. The characteristics of postoperative fibroblastic ingrowth into the anterior chamber are illustrated in figure 1. Gonioscopic examination of the patient whose eye is shown revealed that the fibroblastic ingrowth arose deep in the chamber angle from an incision which was obviously scleral. In the absence of an active inflammatory process in the anterior segment, most fibroblastic ingrowths are self limited, but some need to be checked by ionizing radiation or local applications of cortisone. The commonest complications are occlusion of the pupil and glaucoma; occasionally a separation of the retina below may result from late contraction of a fibroblastic ingrowth into the vitreous above.

In the posterior segment, healing of scleral wounds by secondary intention has a different significance. In the surgery of retinal separation any type of penetrating wound into the interretinal space, whether made by a knife, trephine or diathermy, will result in an ingrowth of fibroblastic tissue which may effectively seal together the two layers of retina, even if there has been no heat or chemical coagulation of the choroid. If the penetrating wound passes through the retina or ciliary body into the vitreous, fibroblasts may grow through the scleral defect and invade the vitreous.

In the healing of a separated wound, there is a tendency for more fibroblasts to grow than are necessary to fill the defect. If there is a fibrin or other framework on which the cells may proliferate, this overgrowth may be extensive. In scleral wounds such a framework may be provided by vitreous or fibrin. As a result, intraocular fibroblastic ingrowth may occur, with later contraction and distortion of the tissue. Histologic study of posterior sclerotomy wounds reveals this to be an almost constant occurrence. It probably accounts for the relative infrequency of retinal separations following such a procedure in spite of the fact that a hole has been made in the retina.

Cellular reactions which occur in the sclera in exudative reactions are either predominantly polymorphonuclear leukocytes or chronic inflammatory cells. The clinical course, complications and sequelae of the two types of processes differ radically. We have designated these two types of exudative reactions the suppurative and the granulomatous types of scleritis.

Suppurative reactions occur whenever the injury incites intense infiltration of tissue with polymorphonuclear leukocytes. Breakdown of these leukocytes releases certain proteolytic enzymes which digest tissue and thereby lead to formation of an abscess. Suppurative lesions in the sclera are not common; but, judging from cases reported in the literature and from several cases observed in our clinic, these lesions can be classified under several types in accordance with their pathogenesis. It is possible to produce a scleral abscess by inoculation of the sclera with pyogenic organisms; however, this is a rare clinical occurrence. Primary suppurative scleritis is almost invariably a metastatic lesion, occurring in association with such pyogenic foci as osteomyelitis, furuncles or dental abscesses. Moreover, the tendency of the lesions to be recurrent and to involve the same eye suggests a localizing hypersensitivity factor. The abscesses in our cases have always been situated anteriorly around proliferating vessels. For example, a woman aged 29 was admitted to the clinic with acute inflammation of the eye. She gave a history of a previous "abscess" on the eyeball many years before. A typical suppurative process was observed to be developing in the sclera just behind the limbus superiorly (fig. 2). General examination revealed an abscessed tooth with evidence of osteomyelitis in the surrounding bone. The patient was treated with massive doses of antibiotics, and the inflammatory process subsided in the eye, leaving a localized staphyloma and postinflammatory glaucoma. The glaucoma was controlled by converting the staphyloma into a filtering cicatrix.

In addition to this primary suppurative scleritis of endogenous origin, there is a secondary type of suppurative scleritis which results from invasion of the sclera by pyogenic processes in adjacent tissue. For example, an elderly diabetic patient was admitted to the clinic with acute panophthalmitis. Examination revealed several

defects in the sclera, with other necrotic areas infiltrated with purulent material. Histologic study of the enucleated eye revealed a suppurative process in the globe with multiple abscesses in the adjacent sclera.

In a strict sense, inflammatory granulomas have come to mean a localized infiltration of tissue with chronic inflammatory cells to form a tumor or swelling. The term "granulomatous scleritis" has been an important addition to our nomenclature because it has permitted the grouping for study of a considerable number of cases of scleritis of diverse etiology but of comparable pathology and clinical course.

Granulomatous scleritis is characterized histologically by infiltration of the sclera with large masses of chronic inflammatory cells. This infiltration and inflammatory edema result in separation and irreparable damage to the fibers. Although extension from the uvea or episcleral tissue into the sclera may occur at any place, granulomatous involvement of the sclera is for the most part limited to areas where the anterior vessels perforate. There is almost always some degree of uveitis associated

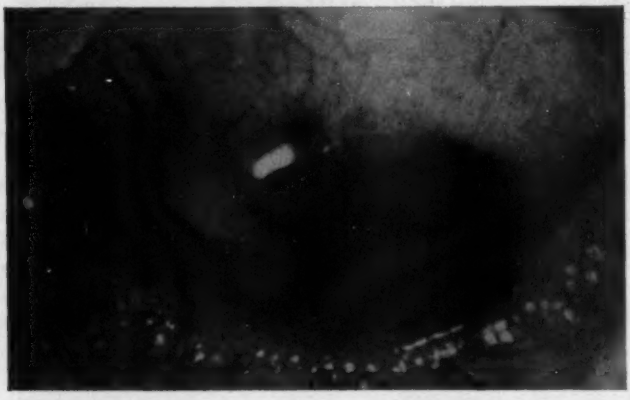


Fig. 2.—Recurrent suppurative scleritis associated with dental abscesses.

with granulomatous scleritis. In many instances the changes in the uveal tract and intraocular fluids may so dominate the clinical picture that the scleritis may be overlooked. The laboratory diagnosis of granulomatous scleritis is, therefore, made far oftener than the clinical diagnosis. It should be suspected in all cases of recalcitrant uveitis of the anterior segment.

The clinical picture of granulomatous scleritis varies with the site and severity of involvement. In most cases the onset is subacute or insidious, with an uncomfortable sensation or aching pain in one or both eyes as the only symptom. Unless the associated uveitis is considerable, there may be little or no disturbance in vision. The process most commonly involves the anterior chamber segment in the region of the perforating vessels. It may extend around the globe to produce an "annular scleritis" but is often localized to one segment. Hyperemia of the episcleral and scleral vessels produces a typical violaceous subconjunctival hue (fig. 3 *A*). The overlying conjunctival vessels are usually engorged, and there may be some conjunctival edema. The involved sclera is frequently thickened and may form local nodules, the so-called

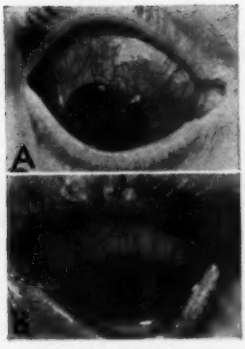


Fig. 3.—*A*, chronic granulatomatous scleritis. *B*, severe granulomatous scleritis following subconjunctival injection of atropine sulfate.

nodular scleritis. In my experience, the presence or absence of nodules has not been a trustworthy indication of the cause.

Granulomatous scleritis tends to run a chronic or recurrent course. During its active phases it is frequently complicated by secondary glaucoma, due to obstruction of the chamber angle by infiltration with inflammatory cells. Extensive peripheral synechias are most likely to develop if the pupil is maintained in a dilated state. Therefore, in cases of this type it is a mistake to use mydriatics for prolonged periods unless gonioscopic examinations are made frequently. As the inflammatory process subsides, localized thinning of the sclera in the anterior segment frequently occurs; consequently, increased visibility of the pigmented ciliary body gives the thinned sclera a typical bluish discoloration. Late cicatrization in the chamber makes postinflammatory glaucoma a common and serious sequela. Lenticular opacities may follow or develop during the course of granulomatous scleritis. Involvement of the cornea is not rare, producing the clinical picture of sclerosing keratitis.

The etiology of the granulomatous scleritis is diverse. Syphilis, tuberculosis and sarcoidosis seem common causative factors. There are, however, many other causative agents. For example, during the winter of 1948-1949 we observed a number of patients in whom bilateral granulomatous scleritis developed in association with an acute infection of the upper respiratory tract. In each patient the bilateral scleritis became manifest six to eight day after the onset of the respiratory infection and ran a course of several weeks. These patients complained of redness of the eye with occasional aching pains, which seemed worse during the night. There was diffuse engorgement of the episcleral and scleral vessels of the anterior segment, with only slight thickening of the episcleral tissues. The globes were tender to palpation only at the site of the process. In each instance there was relatively mild iridocyclitis. In two cases slit lamp biomicroscopy did not reveal keratic precipitates, but "mutton fat" nodules were found deep in the chamber angle on gonioscopic examination. In one patient the nodules were observed to arise from the meshwork and later to extend across to make contact with the iris. In this patient there developed a secondary glaucoma, due to obstruction of the chamber angle.

Chemical and physical irritants are also capable of producing granulomatous types of uveitis. They may produce such an intense infiltration of the tissues that the latter appear "brawny." In 1931 Tooker [3] reported that a "brawny" type of scleritis developed after subconjunctival injections of atropine in a patient with syphilitic uveitis. Berliner [4] reported that a similar type of scleritis developed after repeated injections of mercury salts made to clear the vitreous. During the past several years Butler and I [5] have observed brawny scleritis after the subconjunctival injection of atropine in 5 cases. In these cases injections of 1 to 2 per cent atropine had been made near the limbus by ophthalmologists attempting to disrupt posterior

3. Tooker, C. W.: Annular Scleritis: Report of a Case, Am. J. Ophth. **13**:912-914 (Sept.) 1931.

4. Berliner, M. L.: Biomicroscopy of the Eye: Slit Lamp Microscopy of the Living Eye, New York, Paul B. Hoeber, Inc., 1943, vol. 1, p. 279.

5. Swan, K. C., and Butler, J. B. V.: Brawny Scleritis Following Subconjunctival Injections of Drugs, Tr. Pacific Coast Oto-Ophth. Soc., 1950, to be published.

synechia during the course of an active stage of uveitis. Over a period of days progressive infiltration of the sclera and episcleral tissue occurred, producing the clinical picture of brawny scleritis (fig. 3 *B*). Biopsy of tissue taken in two cases revealed typical granulomatous lesions. Atrophia bulbi developed in two of the cases. In the remaining three cases recovery ensued over a period of several months.

It has not been possible to determine with certainty the role of hypersensitivity in producing the above described reactions to subconjunctival injection; but two of the five patients gave strongly positive reactions to patch tests with atropine, the third gave a doubtful reaction and the remaining two had negative reactions. Under the circumstances localized testing for sensitivity in the conjunctival sac did not seem justified.

The possibility exists that simple chemical irritation to an actively inflamed tissue may have been the precipitating factor. At the pH of the tissues a certain amount of free atropine base, a definite tissue irritant, is liberated. In our cases, as well as in those discussed with other ophthalmologists, there was a common factor of active uveitis; it may be concluded, therefore, that the subconjunctival injection of irritant drugs, like atropine, should be made with extreme caution in patients with active uveitis or scleritis.

Tissue response to subsequent contact with a given chemical, physical or infectious agent may differ dramatically from that resulting from the first contact with the same agent. The agent may then induce a response which generally has the same qualitative features as the first inflammation but is much more violent and acute. Even a minute amount of the agent may induce a violent inflammation when it comes in contact with the sensitized tissue; consequently, this type of reaction, which has been designated as one of hypersensitivity, seems to differ from other tissue reactions primarily in a quantitative manner. A discussion of antibody-antigen reactions is outside the scope of this paper, but it should be stressed that intercellular substances, such as collagen and its ground and cement substances, characteristically seem prone to hypersensitivity reactions. The characteristic of these hypersensitivity responses of collagenous tissue has been a subject of recent investigation by workers in many fields, for it is of importance in relation to a group of diverse processes which are becoming known as collagen tissue diseases, or diffuse collagen diseases because they have in common a predilection for collagenous tissue, such as the sclera, the dermis and the walls of the blood vessels. All seem to have a hypersensitivity component. Examples of these processes are erythema nodosum, periarteritis nodosa, rheumatic fever, disseminated lupus erythematosus and rheumatoid arthritis. Although these processes are commonly designated as "diffuse," or "system," disease, a more proper term seems to be "disseminated" collagenous disease because they are seldom generalized but frequently have areas of disseminated focal lesions. There is considerable evidence not only that the sclera may participate in these disseminated collagen diseases but that some processes may even be localized to it.

The pathologic changes in the collagenous diseases have several outstanding features. The exudative response varies in degree and type with the specific disease process but in most instances consists of chronic inflammatory cells. Most characteristic is the physical change which takes place in the collagen fibers and their

supporting substances. The fibers and fibrils break up and acquire the staining characteristics of a fibrin. The cement substances and ground substances between the fibers and fibrils tend to form characteristic granules and clumps, which can be demonstrated by special stains. These changes in collagenous tissues other than the sclera have been designated as "fibrinoid degeneration."

A few cases of periarteritis nodosa involving the sclera have been reported. One patient with periarteritis nodosa and active scleritis was observed in our clinic. The diagnosis was confirmed by postmortem examination. Recently a patient was admitted with typical nodules of erythema nodosum on the extensor surfaces of the limbs. Biopsy of one lesion confirmed the clinical diagnosis. In association with the involvement of the skin, mild iridocyclitis and an elevated nodule developed in the sclera near the limbus of one eye (fig. 4). This lesion had many of the clinical features of a phlycten in that it was a solid subepithelial nodule associated with

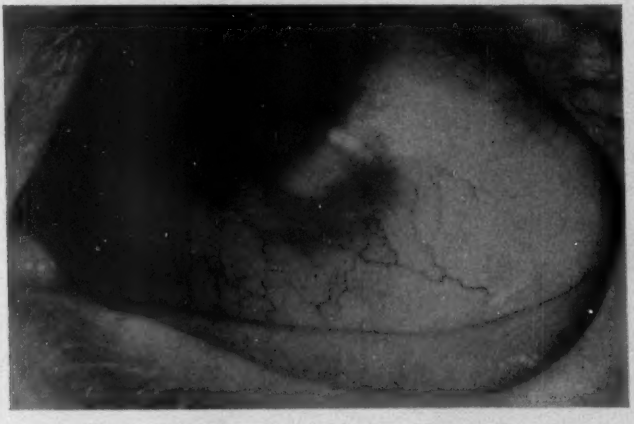


Fig. 4.—Scleral lesion associated with erythema nodosum.

violent hyperemia of the surrounding conjunctival and episcleral vessels; however, it did not break down. The scleral inflammation subsided over a period of weeks at the same rate as resolution of the nodules of the extensor surfaces of the legs.

Rheumatoid arthritis is a disease which frequently displays lesions in collagenous tissue, including the sclera. Clinical signs of involvement of the collagenous tissue of the sclera are usually much less striking than the commonly associated uveitis, but histologic study of eyes with uveitis associated with rheumatoid disease which have been enucleated frequently has revealed infiltration of the anterior sclera with chronic inflammatory cells or disruption or splitting of the fibers and alterations in their staining characteristics. A clinical diagnosis of scleritis had been made in only a small percentage of patients with rheumatoid arthritis. It is not intended to imply that the scleritis of rheumatoid arthritis is always subclinical, for there are many cases in which gross involvement of the sclera, episclera and surrounding loose connective tissue of Tenon's capsule occurs, as evidenced by intense engorgement of the

vessels in an area of one third or one half of the globe. Symptoms are usually aching pain or an uneasy feeling, but several of our patients have come to the clinic only because they noticed that the eye appeared hyperemic. Edema of the overlying conjunctiva is common but is seldom sufficiently severe to produce an appreciable conjunctival exudate. Occurrence of the scleritis does not show a definite relation to the involvement of the joints. Initially the attacks tend to be recurrent with considerable periods of remission, but eventually in many cases the condition becomes chronic. The immediate response of acute scleritis to systemic administra-

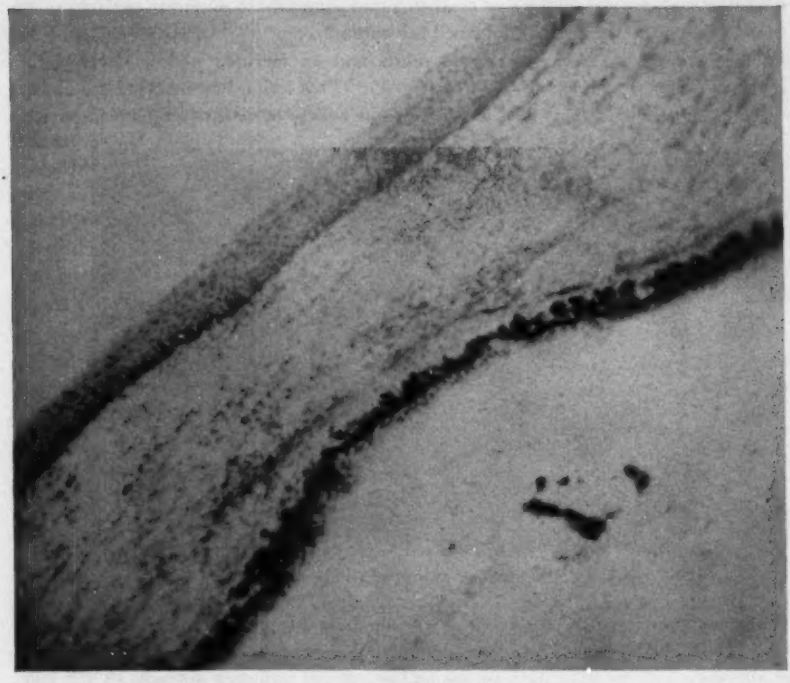


Fig. 5.—"Scleromalacia perforans," with marked subepithelial atrophy of the conjunctiva and episclera, infiltration of the sclera with chronic inflammatory cells and area of dissolution of the sclera over the flat part of the ciliary body.

tion of pituitary adrenocorticotropic hormone (ACTH) or cortisone might be expected to be spectacular.

A type of scleral lesion which may occur in association with arthritis, and which seems to fit into the category of disseminated collagenous diseases, is the condition commonly designated as scleromalacia perforans. One might assume from the handful of cases reported in the literature that it is rare; however, it should be pointed out that the process has received attention only in the past few decades and is probably uncommon but not extremely rare. Three patients with this lesion have been observed in the University of Oregon Clinics in the last four years.

Scleromalacia perforans has been described by Duke-Elder[6] and others as a process in which focal areas of necrosis and sequestration develop in the sclera with little inflammatory reaction. In each of our three patients a local area of necrosis developed in the sclera with the extrusion of yellow sequestra through the conjunctiva. One patient, who was seen through the courtesy of Dr. F. Kiehle,[7] had huge scleral defects. All three patients had involvement of the bones and joints.

Scleromalacia perforans is a misleading term, because it implies that the process is primarily scleral and is in the nature of a softening process which leads to weakening and perforation. In reality, the scleral involvement may predominate, but it is only one phase of a marked atrophy of other connective tissues about the eye. There is pronounced loss of the loose submucosal connective tissue of the conjunctiva and Tenon's capsule, so that the epithelium tends to become adherent to the globe and loses some of its mucoid characteristics (fig. 5). Atrophy of the subepithelial tissue

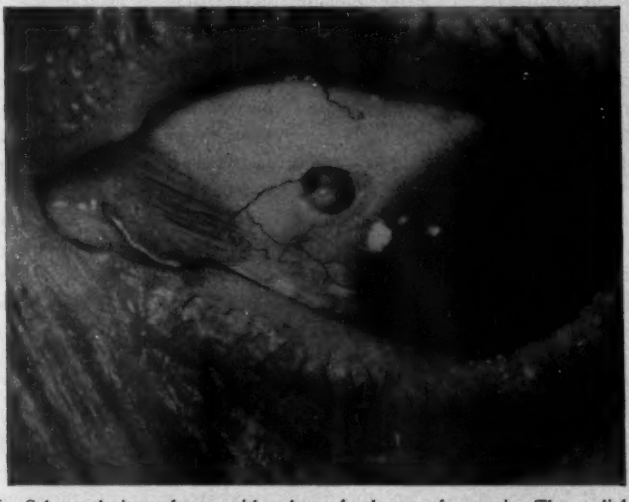


Fig. 6.—Scleromalacia perforans with a large focal area of necrosis. The medial rectus is visible through the thinned conjunctiva because the subepithelial tissue is atrophic.

is strikingly evidenced by increased transparency of the conjunctiva. Detailed structure of the rectus muscles can be readily observed (fig. 6). There also seem to be atrophic changes in the connective tissue of the orbit. In Kiehle's patient the extraocular muscles became so fibrotic that rotations of the globe were greatly limited.[7]

In previous descriptions of scleromalacia perforans, the process generally has been discussed as focal necrosis with little inflammatory response. It is true that the classic symptoms of inflammation are absent, because in injury to relatively avascular intercellular substances, such as collagen, there may be little exudate or

6. Duke-Elder, W. S.: Text-Book of Ophthalmology, vol. 2, St. Louis, C. V. Mosby Company, 1938, p. 2066.

7. Kiehle, F. A.: Scleromalacia, Am. J. Ophth. **29**:862-863 (July) 1946.

infiltration with inflammatory cells. Notable vascular changes may be absent even in the presence of severe damage. Histologic study of the enucleated eye of one of our patients revealed focal areas of fragmentation of collagen fibers, separation of fibrils and collections of the ground substances into granular clumps. The histologic picture was that of "fibrinoid degeneration" of collagen. Sequestra of necrotic scleral tissue could be seen extruding through the conjunctiva. The fibers and fibrils in the involved area of the sclera were infiltrated with chronic inflammatory cells. Cells of the same type were prevalent also in the adjacent uveal tract. In brief, study of our cases suggests that so-called scleromalacia perforans is an inflammatory process involving all the connective tissue of the globe and its adnexa and belonging to the group of collagen diseases. The dominant feature is atrophy and necrosis of the collagen tissue with relatively little vascular and cellular response.

The cellular response which does occur in so-called scleromalacia perforans is primarily in the nature of chronic inflammatory cells, with little tendency toward proliferation of the fibroblasts. In this respect the postoperative course of one of our patients was interesting. This woman, aged 69, had bilateral cortical cataract which reduced visual acuity to light perception. A limbic incision was made, and the lens was extracted. The postoperative course was uncomplicated, but even a year after the extraction the incision was evident under the epithelium as a dark line with direct illumination and as a semitransparent line with retroillumination; that is, there had been no appreciable formation of collagen in the scar.

Phlyctenular disease is another localized inflammatory process with many of the features of the collagenous diseases, including a possible hypersensitive component. Involvement of the sclera has received little or no attention. In severe cases scleral involvement may be conspicuous. Among the Indians of the Pacific Northwest, phlyctenular disease may be severe, and in some cases focal areas of dissolution of the sclera occur during the height of the process (fig. 7). Areas of scleral atrophy are not rare in phlyctenular diseases and offer a clue to the diagnosis of the process.

In the time-honored method of classifying disease processes, degenerations are distinguished from inflammations. As knowledge of the pathogenesis of disease progresses, it becomes increasingly difficult to draw a sharp line between these tissue reactions. It has become evident that many processes which were formerly considered degenerative are in effect simply indirect injury to the tissue resulting from disturbances in metabolism. The metabolic disturbance which disrupts function and produces changes in the tissue may not even be the result of an exogenous agent, but may be merely an upset in hormonal balance, a nutritional inadequacy or a hereditary metabolic fault. Nevertheless, an injury to tissue results and a response occurs. In the sclera, osteogenesis imperfecta is the cardinal example of a tissue change resulting indirectly from altered metabolism. A number of physicochemical changes occur in the sclera which are not the result of direct injury, nor are they associated with an appreciable degree of cellular or vascular responses. These we have designated as scleropathies. Perhaps the commonest and most striking change of this type is the formation of semitransparent, vertical plaques in the sclera in front of the insertion of the rectus muscles (fig. 7). Histologic study of the plaques reveals them to be homogeneous and lacking in the normal fibrillar structure of the sclera; therefore, they have been designated by a number of authors as "hyalin

plaques."[8] It should be pointed out that hyalin is not a specific substance but simply represents a change in the physical state of the tissue without any decided change in its chemical constituency. Hyaline plaques are much commoner in the

Fig. 7.—End result of severe phlyctenular keratoscleritis in an Indian boy. The sclera was destroyed in large areas of the anterior segment. The cornea was badly damaged but remained intact.

Fig. 8.—Scleral hyalinization.

sclera than the literature would indicate. They are generally considered to be a process of senility, but they are frequently observed in minor degree in patients in

8. Roper, K. L.: Senile Hyaline Scleral Plaques, Arch. Ophth. **34**:283-291 (Oct.) 1945.

the middle fifties. In a series of more than 100 patients with scleral hyaline plaques seen in our clinic, the most commonly associated systemic finding was osteoarthritis. This was present in sufficient degree to produce symptoms in more than 60 per cent of the patients. In a number of asymptomatic patients there was roentgenologic evidence of this type of joint involvement. Unfortunately, complete roentgenologic studies were not possible on all patients.

In correlating the presence of other ocular abnormalities with hyaline plaques, we found that a senile type of cataract was present in an appreciable percentage of cases. The frequency of opacities in the lens in association with hyaline plaques in the sclera resulted in cataract extraction being performed on more than 20 of these patients. There seemed nothing unusual about the postoperative course of these patients except that healing of the wound seemed lower than usual. The series is

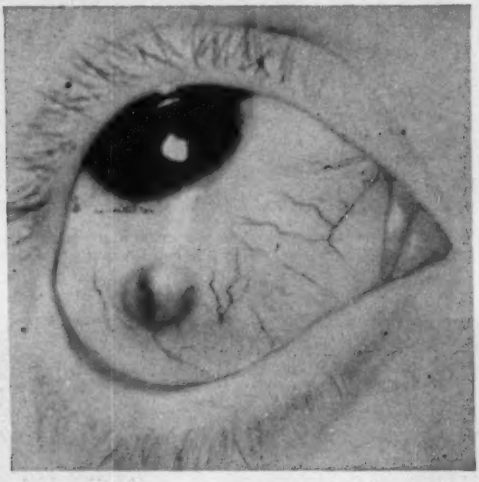


Fig. 9.—Staphyloma developing in a ciliary body after focal blunt injury to a child's eye.

too small to be of statistical significance, but it indicates that the presence of these plaques does not contraindicate surgical procedures on the anterior segment.

Atrophy of the sclera in association with an inflammatory process, such as granulomatous scleritis and phlyctenular disease, has already been discussed.

Areas of atrophy occasionally are evident in middle-aged and elderly persons as thinning of the sclera and gross enlargement of the openings in the sclera through which the anterior vessels perforate. The basis for this type of scleropathy and its relation to systemic disease have not been determined.

Individual branch fibers of the sclera, like the individual fibrillae in other tissues, can be distended to many times their length, but the lateral binding of fibrillae to each other by an intercellular substance is apparently so strong that the distensibility of collagen fibers is greatly reduced. There seems little doubt that in the overwhelming majority of elderly patients the sclera has a remarkable resistance to increased intraocular pressure. When one considers the strength in similar tissue in

the joints, this is understandable; however, there is an occasional case of chronic, long-standing glaucoma in which extreme thinning of the sclera occurs in the anterior segment without localized staphyloma formation. Several cases of this type have been observed in our clinic. In these cases it has not been possible to rule out the presence of preexisting scleritis, but no signs of exudative reaction have been evident, and in each instance there has been a history of long-standing increased intraocular pressure.

In infants, lateral binding of individual scleral fibrillae seems weak, so that distention of the globe occurs with abnormally increased intraocular pressure. Development of lateral binding of fibrillae seems to occur throughout childhood. Clinically, this is manifested by a difference in response of the sclera of children and adults to focal blunt injury. Local staphylomas frequently develop some months after a child has received a blunt injury to the globe (fig. 9), are less common in young adults and are rare in older people. Occasionally such a post-traumatic staphyloma in a child may lead to retinal separation.[9] For example, a retinal separation developed in an 8 year old boy six months after a blunt injury to the globe. A localized staphyloma was found near the equator in the region of the separation. This area was resected and studied histologically. Fibrosis was not observed, but some fibers were greatly thinned and a few were disrupted. In effect, the morphologic character of the fibers was grossly altered without histologic evidence of reparative response. This type of physical change resulting from injury, without exudative or proliferative reactions, typically occurs in collagenous tissues in areas which are relatively acellular and in avascular areas.

In closing this lecture given in memory of Dr. Charles H. May, I repeat that diseases of the sclera have been a neglected chapter in modern ophthalmology. This neglect can be attributed in good part to the generally accepted view that the sclera is an inert fibrous tunic which is seldom involved in inflammatory disease processes. I believe that this view is erroneous and that the sclera should be considered an intercellular collagenous tissue which may be, and often is, affected by many of the local and systemic disease processes that affect such tissues. Other deterrents to knowledge of scleral inflammation have been outmoded systems of classification based on symptomatology or site of involvement and an etiology inadequate for diagnosis on the basis of causative factors.

The responses of the sclera to injury have been the subject of interest at the University of Oregon Medical School for several years. It has been observed that these responses, although diverse, follow certain definite patterns which can be correlated with causative factors, symptomatology, responses to therapy and associated or contributory systemic disease. Classification of scleral inflammations in accordance with the tissue responses to injury has provided a workable basis for clinic management of individual patients, as well as the grouping of cases for research purposes.

A classification of scleral inflammation on this basis includes proliferative and exudative types, as well as those groups in which the responses are predominantly physical and/or chemical. Types of responses, such as "fibrinoid degeneration,"

9. Vail, D. T.: Scleral-Resection (Eyeball-Shortening) Operation, Am. J. Ophth. **29**:785-799 (July) 1946.

merit special attention, along with the responses of the sclera to the indirect injuries of metabolic and nutritional origin. The latter have been designated as sclero-pathies.

1. Proliferative scleritis, e. g., fibroblastic ingrowths following scleral wounds
2. Exudative scleritis
   (*a*) Granulomatous
   (*b*) Suppurative
3. Scleritis associated with fibrinoid degeneration, e. g., "scleromalacia perforans"
4. Physical and/or chemical changes resulting from injury but with negligible or absence of response, e. g., staphyloma formation after blunt injury
5. Scleropathies (physical and/or chemical changes associated with indirect injuries of nutritional or metabolic origin), e. g., hyaline plaques

These general classes of scleral inflammations, on a pathologic basis, which are summarized in the tabulation, have some subclassifications, for they are modified by such factors as hypersensitivity and anatomical differences of age. It is suggested that weak lateral binding of individual scleral fibrillae to each other in infancy and childhood is the probable explanation for the stretching of the globe which occurs after blunt injury or glaucoma in the early years of life but not in older adults.

CAUSE OF FAILURE IN RETINAL DETACHMENT SURGERY

P. ROBB McDONALD, M.D.
PHILADELPHIA

WITH THE increase in longevity of the population, one can expect an increase in the number of retinal detachments seen. Detachment of the retina is to a large extent the result of degenerative processes in the eye, and until some method of arresting these processes can be found one can expect an increase in the incidence of this disease.

It is human nature to be encouraged by success and to be discouraged by failure. An analysis of failures, however painful, is frequently enlightening. Koenig [1] has recently reported his failures in a small series, and the total number of patients in the present series is likewise small. Of a total of 88 patients, 24 were listed as failures. They represent cases in which I operated during the past 3½ years. For the most part, the patients were followed in the office, or adequate data have been obtained from the referring physician. These cases represent a fair cross section of the type of detachment seen. Some of the expressed opinions are on the basis of patients seen in consultation but on whom I did not operate.

Causes of failure in detachment surgery can roughly be placed in three categories according to the period in which they occur, the order being that of their importance: (1) the preoperative period, (2) the operative procedure and (3) the postoperative period.

THE PREOPERATIVE PERIOD

The most important cause of failure referable to the preoperative period is failure to perform a complete examination of the patient. One feature frequently neglected is the taking of a good history. The patient is occasionally seen propped up in bed because of an inferior detachment, with a notation that no hole was seen. The history reveals a shower of vitreous opacities or sparks noted in the lower field, and examination shows a tear in the comparatively flat upper portion of the retina. One of the failures in the present series was in a case of this nature. The patient had had two overly zealous operations on the lower half of the retina before being referred for further surgery. A hole was clearly visible above, but thick, fixed folds of retina below prevented closure of the hole. The most important feature of

From the Wills Hospital.

Presented before the College of Physicians of Philadelphia, Section on Ophthalmology, Dec. 21, 1950.

1. Koenig, I. J.: Failures in Retinal Detachment Surgery, New York J. Med. 49:2405 (Oct.) 1949.

detachment surgery is to find the tear in the retina, and one should not be content with the finding of one tear but should always suspect the presence of another. There are three prerequisites to the finding of tears or breaks in the retina: perseverance, a maximal dilation of the pupil and a good ophthalmoscope. Schepens [2] has recently recommended a mixture of homatropine, phenylephrine (neo-synephrin®) hydrochloride and procaine for subconjunctival injection prior to examination of the fundus. There is no question that in his hands indirect ophthalmoscopy with his instrument permits a much more extensive view of the peripheral retina than that obtained with direct ophthalmoscopy. Until his instrument is available, one must be content with American- or British-made ophthalmoscopes. The 6 and 12 volt instruments available are greatly superior to any battery handle ophthalmoscope.

Peripheral holes are frequently made visible with pressure over the ora serrata, using a muscle hook or the instrument devised by Schepens.[2] Should the retina settle back quickly and no hole be seen, the patient should be repostured or permitted out of bed to allow the detachment to reoccur. Frequently a tear will then become visible. This procedure was neglected in one case early in this series, and its omission is believed to have been the cause of failure. In this series one or more tears were found in 86 per cent of the successful cases, whereas they were found in only 33 per cent of the unsuccessful cases!

Other features affecting the prognosis are the size of the tear, the extent of the detachment, the duration of the detachment and the condition of the retina. An extensive and large tear in the retina as a rule is harder to close than multiple small tears. In this series there was one case with a tear near the equator involving more than one quadrant of the retina and another with complete disinsertion of the temporal half of the retina from 12 to 6 o'clock. The free edge of the retina could be seen splitting the pupillary opening vertically—in both cases operation was unsuccessful. Among the cases of failures were five with complete detachments, (three with aphakia), and only in two of the 24 cases was less than one-half the retina detached. In one case a complete detachment was successfully operated on. In most of the successful cases not more than one-half the retina was detached.

Appleby and Pischel,[3] Shipman,[4] Arruga [5] and others have shown that there is a definite correlation between the duration of the detachment and the prognosis. Of the 24 cases of failures, the detachment was of less than one month's duration in 11; of one to two months' duration, in 7, and of three months to seven years' duration in the rest. These statistics do not appear to agree with the other authors; so further elucidation is necessary. Of patients with detachments of less than one month's duration, four were aphakic and noted symptoms immediately after operation; two had intraocular foreign bodies; two had 6/9 vision for six to nine

2. Schepens, C. L.: Progress in Detachment Surgery, Tr. Am. Acad. Ophth., to be published.

3. Appleby, R., and Pischel, D. K.: Review of 100 Cases of Retinal Detachment, Am. J. Ophth. **31**:796 (July) 1948.

4. Shipman, J. S.: Some Practical Facts Regarding Retinal Detachment Surgery, with a Report of the Results in over 400 Selected and Consecutive Cases, Am. J. Ophth. **33**:847 (June) 1950.

5. Arruga, H.: Le prognostic dans le traitement chirurgical du décollement de la rétine, Bull. et mém. Soc. franç. opht. **48**:348, 1935.

weeks in the eye operated on, and detachments then developed in the diametrically opposite portion of the retina, the patients refusing further operation, and two had myopia of — 20 to — 24 D., respectively.

Of considerable importance is the appearance of the retina and vitreous. The presence of what Schepens [6] calls fixed retinal folds definitely lowers the chances for a good result. The folds appear frozen, and the retina and overlying vessels may show torsion from traction of vitreous bands. These folds usually radiate from the posterior pole of the globe toward the equator. Near the equator there may be a circular fold, which appears as a ridge in the fundus. This type of fold is seen most frequently in aphakic eyes and is believed to be due to massive vitreous retraction. With suitable slit lamp examination of the fundus, the vitreous may be seen adherent to the retina. Another clue is the failure of the folds to change position with bed rest.

Most ophthalmologists are pessimistic about the prognosis for detachment of the retina in aphakic patients. Schepens [6] has recently reviewed this subject and has made a definite contribution to our understanding of this difficult problem. There is no doubt that failures are frequently caused by inability to find the tear, the danger being further accentuated by capsular remnants if they are present. Schepens,[6] Arruga [5] and others believe that massive vitreous retraction is the cause in many instances. In this series there were 12 cases of aphakia and 6 cases of failures. Of the patients for whom operation failed, two were under 50 years of age and had ectopia lentis, the lens being removed with a loop. In one the detachment had been present nine months, and in the other retinitis proliferans was noted prior to removal of the lens. Two others had complete funnel detachments, the lesion being present in one for seven years, and the other had a mere pinpoint opening in a dense capsule. In the two remaining patients detachment had developed in one eye almost immediately after cataract extraction. In each case the same sequence of events followed removal of the cataract in the remaining eye. The patients were then referred for detachment surgery. The detachments were complete but operation was performed, since it was their only chance of retaining any vision. One cannot help but wonder whether the same degenerative processes are not sometimes involved in the development of cataract and retinal detachment and whether the detachment might not have been present and unrecognized prior to removal of the lens.

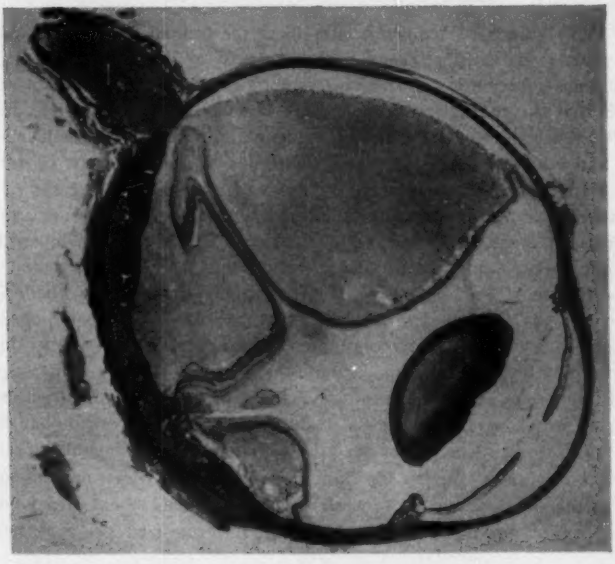
A history of trauma, especially indirect trauma, is frequently difficult to evaluate. There is no question that in many cases of retinal detachment the symptoms are first noted after indirect trauma, such as a fall or a light blow on the head. It is not believed that such indirect trauma affects the prognosis. However, direct trauma sufficient to cause a retinal detachment does affect the end result.[7] Three patients with intraocular foreign bodies and retinal detachments were operated on unsuccessfully. In one case the foreign body had been in the eye unrecognized for two years. Gradual failure in vision was noted only two months before the patient was referred for detachment surgery. The foreign body was removed at the time of the attempted repair of the detachment. In another case the detachment was noted before the

6. Schepens, C. L.: Retinal Detachment and Aphakia, A. M. A. Arch. Ophth. **45**:1 (Jan.) 1951.

7. Fink A. I.: Detachment of the Retina in Young Adults: An Analysis of the Treatment of a Young Age Group at an Army General Hospital, Am. J. Ophth. **33**:424 (March) 1950.

patient was aware of an intraocular foreign body. In the third case a massive vitreous hemorrhage occurred at the time of the original injury. The foreign body was delivered from the pars plana, but two years later, when the media cleared, retinitis proliferans and a detachment were noted. Attempted repair of the detachment was unsuccessful. In another case a kick directly on the globe resulted in disinsertion of over half the retina, and operation was unsuccessful. In this case a scleral resection might have been the operation of choice.

High myopia is another feature that adversely affects the prognosis. Dunnington and Macnie [8] stated that in their series only 48 per cent of patients having a myopia of greater than 6 D. were cured. Two of our failures were in patients with myopia of — 20 to — 24 D. A view of the fundus was difficult because of disturb-



Flat metastatic carcinoma involving the lower portion of the globe. The retina can be seen adherent to the tumor at the site of the trephine opening.

ances in the media. One of these patients had a massive vitreous hemorrhage on the fourth postoperative day, and useful vision was lost.

The presence of uveitis is usually considered to affect the prognosis adversely.[9] Appleby and Pischel,[3] in a review of 100 cases, considered four patients as having iridocyclitis as a complication of retinal detachment. It is difficult at times to ascertain whether the uveitis is active or not. The presence of a few cells in the aqueous and vitreous is frequently noted in patients with detachment. A ciliary flush with a definite flare, however, is indicative of activity. In the present series two such active

8. Dunnington, J. H., and Macnie, J. P.: Detachment of the Retina: Operative Results in 164 Cases, Arch. Ophth. **18**:532 (Oct.) 1937.

9. Koenig.[1] Arruga.[5]

cases occurred. In one the retina settled back rapidly. No hole was found, and the choroidal reaction following minimal surgical intervention resulted in a heavy grayish white detachment of the retina. Fortunately, in the second case three large holes were found. Despite a tension of 11 mm. of mercury (Schiøtz) and previous operation for secondary glaucoma, this one-eyed patient has maintained 6/6 vision for two years.

Another cause of failure must be mentioned; that is incorrect diagnosis. Berens and associates [10] and Reese [11] have reported cases in which an operation for retinal detachment was performed on eyes subsequently determined to have an intraocular tumor. In the present series operation was performed in one case of metastatic carcinoma of the choroid, with what appeared to be a serous detachment. The diagnosis of neoplasm is sometimes extremely difficult. The patient in question was known to have had a radical mastectomy for carcinoma. She had none of the signs of a solid detachment, except that no tear was found. At operation the penetrating pins could not be visualized clearly, and no subretinal fluid was obtained on their withdrawal. The sclera was trephined, with release of a small amount of subretinal fluid, and the scleral plug sent to the laboratory. Dr. J. S. McGavic reported adenocarcinomatous cells, and the eye was subsequently enucleated. The section shows a flat metastatic lesion underlying the area of detachment (figure).

OPERATIVE PROCEDURE

Failures due to the operative procedure are fortunately rare. As mentioned previously, careful ophthalmoscopic control during the course of the operation is essential. This necessitates a clear cornea and well dilated pupil. The tear should be well localized prior to operation by Stine's method,[12] as well as directly during the course of operation. Two causes of failure are believed to be inadequate diathermy or too much diathermy. In two patients in this series the retina settled back rapidly, in fact, so rapidly that the resident had difficulty in finding the detachment 24 hours after the patient's admission. No holes were seen, and what was considered a minimal amount of partial penetrating diathermy was used over the original limits of the detachment. The choroid responded with a tremendous amount of exudation, and on examination following operation grayish white, elevated folds of retina, much greater than the original detachment, were seen. A second operation merely aggravated the original insult, and complete detachment ensued. This may have been due to an unrecognized uveitis, as suggested by Arruga.[13]

Inadequate diathermy no doubt is the cause of some failures. This is especially true in cases in which rents or cysts are present in the extreme periphery and are not visible by the ordinary methods of ophthalmoscopy.

10. Berens, C.; Hall, D. S.; Smith, B., and McAlpine, P. T.: Late Results of Operations for Separation of the Retina: Report of 304 Operations Performed at the New York Eye and Ear Infirmary from 1929-1938, Surg., Gynec. & Obst. **70**:454 (Feb.) 1940.

11. Reese, A. B., in discussion in symposium on Retinal Detachment, Am. J. Ophth. **25**:1246 (Oct.) 1942.

12. Stine, G. H.: Tables for Accurate Retinal Localization, Am. J. Ophth. **17**:314 (April) 1934.

13. Arruga, H.: Considerations on the Treatment of Detachment of the Retina, Proc. Roy. Soc. Med. **41**:68, 1948.

Injury to the vortex veins or to the retinal vessels during the course of the operation is a rare complication. One may see retinal hemorrhages occur during the course of examination, but in the present series when this occurred gradual absorption took place without deleterious effect on the final result. During the course of the operation the intraocular tension may be increased by shrinkage of the sclera. This increased pressure clouds the cornea and may obscure any view of the fundus. Schepens [2] claimed that the intraocular tension may be elevated as high as 90 mm. of mercury (Schiøtz) and in secondary operations may lead to rupture of the sclera.

One of the annoying operative complications is the insufficient drainage of subretinal fluid or the opposite, that of losing subretinal fluid early in the procedure. Various methods, such as posterior sclerotomy, trephination of the sclera and use of quill pins or penetrating pins, are employed to obtain drainage of subretinal fluid. Most surgeons agree that it is better to have fluid seeping through two or three holes than through one large hole. Occasionally, despite the conventional use of penetrating pins or needles, the subretinal fluid does not flow out adequately. I have noted this in cases of long-standing detachment and in other cases in which considerable diathermy has been used. What little fluid did escape was viscid and gave the impression of partially coagulated subretinal fluid. The injection of air or saline solution into the posterior chamber in phakic patients or into the anterior chamber in aphakic patients may force out more fluid and place the retina against the choroid. The failures in two patients operated on early in this series are accredited to inadequate release of subretinal fluid. In one, trephination was resorted to. This resulted in a severe subchoroidal hemorrhage, with resultant failure. There are occasions, however, when after release of considerable subretinal fluid the retina does not appear to be in place. This may be due to the fact that the eyeball is so soft that the retina remains elevated. When the tension is built up, the retina will assume its proper place against the choroid.

POSTOPERATIVE PERIOD

In the absence of disturbance of the vitreous, examination of the fundus at the end of seven days usually reveals the retina to be in place, though elevated because of the choroidal reaction. In two cases in this small series large dark areas of detachment were seen contiguous to the site of operation. In the first patient this condition was not recognized as a choroidal detachment, but the subsequent course proved this to be the case. In the second patient the choroidal detachment was even more extensive. This is a complication that is rarely mentioned.[14] Its correct interpretation will undoubtedly relieve the surgeon of some anxiety.

It is difficult to classify postoperative causes of failure. Postoperative uveitis in a mild form is frequently seen. The occurrence of a severer form, manifested by ciliary injection, poor dilatation of the pupil, an increase in the vitreous haze and a rapid increase in preexisting opacities in the lens, usually signifies failure. This may be caused by reactivation of a preexisting uveitis or excessive diathermy in the region of the ciliary body. This complication occurred once in my series. Prior to

14. Schiff-Wertheimer, S., and Frileux, R.: Complications post-opératoires aprés traitement chirurgical du décollement de la rétine par diathermo-coagulation, Bull. et mém. Soc. franç. opht. **59**:265, 1940-1946.

operation a good view of the fundus was impossible because of marked lenticular changes. Approximately three fourths of the retina was detached, the most elevated portion being in the region of the equator. No tear could be seen. After operation there was evidence of moderately severe iridocyclitis, and useful vision was lost.

In one patient in this series a massive choroidal hemorrhage developed on the fifth postoperative day. There was considerable pain, and blood could be seen seeping into the anterior chamber. Unruliness on the part of the patient may be blamed for failure, but some excellent results are found in patients who do not behave well. One patient in this series with a detachment of the superior portion of the retina sat up in bed and walked around when unattended during the first postoperative week. The operation was unsuccessful. One might or might not be justified in classifying this case as one of failure due to the fault of the patient.

One complication that has been seen in two cases in this series is that of having the diametrically opposite part of the retina detach six to nine weeks after the original operation. In two of them opercular-like holes could be seen developing in the region of the equator as the vitreous contracted. Neither of the two patients would submit to further operation, despite the fact that they had had better than 6/12 vision for some time after operation. Another patient listed as a failure had 6/9 vision for four months. He originally had a series of small holes running horizontally just in front of the equator below, between 5 and 7 o'clock. The areas of coagulation could be clearly seen and did not appear too heavy or extensive. About the sixteenth week a new series of holes appeared in front of the original ones. I had the impression that the retina was shrinking. The vitreous appeared relatively clear, and no recognizable traction bands could be seen. The patient refused operation; so the result was listed as a failure.

Postoperative recurrence of detachment in an area contiguous to that originally treated is usually due to inadequate primary closure of the tear. Detachment occurring in a previously uninvolved portion of the retina may be caused by contraction of the vitreous, but may also be due to a small tear that was unrecognized at the time of the first operation. Definite visible tears have been noted and followed for months without a detachment developing.

SUMMARY

Of a total of 88 cases in which operation was performed for detachment of the retina, the results in 24 were listed as failures. Of considerable prognostic importance are the size of the tear, the condition of the retina and vitreous, the presence of high myopia and a history of direct trauma to the eye. Listed among the failures were two cases in which tears involved more than one quadrant of the retina, six cases of aphakia with evidence of disorganization of the vitreous, two cases of myopia, with 20 D. of myopia, and three cases of intraocular foreign bodies. In one case of uveitis and in another with a metastatic adenocarcinoma of the choroid operation was also performed, without success.

The operative causes of failure, fortunately, are rare. Excessive diathermy, especially in a case of unrecognized posterior uveitis, may cause an increase in the extent and severity of the detachment. This was considered to be the cause of failure in two cases. Inadequate drainage of partially coagulated subretinal fluid may adversely affect the prognosis. Trephination in one such case resulted in a severe subchoroidal hemorrhage with loss of useful vision.

Postoperative uveitis and massive choroidal hemorrhage contributed to failure in two cases. Another complication noted in three cases in this series was that of having the diametrically opposite portion of the retina detach six to eight weeks after the original operation. This may have been due to contraction of the vitreous or failure to close an unrecognized tear.

Success or failure will, of course, vary in the selection of cases for operation. During the period in which this series was compiled, five patients with retinal detachments were seen but not operated on. Three had had two to five previous operations, and two were frail aphakic patients over 70 years of age.

Retinal tears were found in 86 per cent of the successful cases and in only 33 per cent of the unsuccessful cases.

The two most important factors contributing to failure would appear to be inability to locate the tear in the retina and disorganization of the retina and vitreous.

RATE OF TURNOVER OF ASCORBIC ACID IN AQUEOUS HUMOR IN RABBITS

BERNARD BECKER, M.D.
BALTIMORE
ERIK LINNER, A.B.
AND
ERNST BARANY, M.D.
UPPSALA, SWEDEN

THE RATE of turnover of ascorbic acid in the aqueous humor has been determined by two independent methods. Friedenwald and collaborators [1] injected large amounts of ascorbic acid into the anterior chamber and observed a rate of disappearance of 0.8 per cent per minute. However, this value was obtained under obviously unphysiological conditions. Kinsey and Barany [2] used a different method, based on the rate of entrance of ascorbic acid into the aqueous at high plasma levels. Kinsey [3] had observed that the concentration of ascorbic acid in the aqueous was nearly constant above a certain critical plasma level. The plasma level was accordingly raised quickly above this critical concentration and kept there for a period of hours. The concentration of ascorbic acid in the aqueous in these circumstances rose and approached a ceiling of about 50 mg. per 100 cc. asymptotically with a rate constant of 1 per cent per minute. In order that the rate of turnover of ascorbic acid might be determined by this method, both eyes had to be punctured at a certain time interval. It has been found recently (Barany, Becker and Linner [4]) that in certain rabbits puncture of one eye caused up to a 29 per cent increase in the ascorbic acid level of the opposite eye one or two hours later. This change occurred without increase in the blood level of ascorbic acid, but the blood dehydroascorbic acid was not measured. If this effect is due to an increase in the plasma level of dehydroascorbic acid, it would probably not have appeared at artificially increased plasma levels exceeding the saturation point. However, the rate of turnover of ascorbic acid and of aqueous may very well be abnormal at such high plasma ascorbic acid levels. Therefore, it was thought desirable to determine the rate of turnover of ascorbic acid by a completely independent method and at physiological

This study was supported by a grant from the Swedish Medical Research Council.

From the Wilmer Ophthalmological Institute, Johns Hopkins Hospital (Dr. Becker), and the Pharmacological Institute, University of Uppsala (Drs. Linner and Barany).

1. Friedenwald, J. S.; Buschke, W., and Michel, H. O.: Role of Ascorbic Acid (Vitamin C) in Secretion of Intraocular Fluid, Tr. Am. Ophth. Soc. **37**:310, 1939; Arch. Ophth. **29**:535 (April) 1943.

2. Kinsey, V. E., and Barany, E. H.: The Rate of Flow of Aqueous Humour: Derivation of Rate of Flow and Its Physiologic Significance, Am. J. Ophth. **32**:183 (June, pt. 2) 1949.

3. Kinsey, V. E.: Transfer of Ascorbic Acid and Related Compounds Across the Blood Aqueous Barrier, Am. J. Ophth. **30**:1262, 1947.

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concentrations. This was accomplished by the method described below, which admittedly introduced unphysiological conditions, but of an entirely different nature.

PRINCIPLE OF THE METHOD

The method is based on the observation of Linner [5] that occlusion of one carotid artery in rabbits lowers the ascorbic acid content of the aqueous of the homolateral eye. From chart 1 it may be seen how this observation can be used for determination of the rate of turnover.

One carotid artery of a rabbit is temporarily clamped and the ascorbic acid level in that eye allowed to approach its new equilibrium concentration (chart 1, *A-B*). At a suitable time t_1, the clamp is removed and the other carotid artery occluded. The ascorbic acid level in the first eye, after removal of the clamp, rises along the curve *B-C*. At the same time the level in the second eye falls (*D-E*). The intersection between the curves *BC* and *DE* occurs at a time t_2. The time interval t_2-t_1 is an approximate measure of the half-life of ascorbic acid, if one can neglect changes in rate of turnover with carotid occlusion and factors related to reactive hyperemia and collateral circulation. Thus, by determining the unique time at which both eyes have the same ascorbic acid levels, one has a direct measurement of the half-life, and thus of the rate of turnover of ascorbic acid in the aqueous.

For a more precise determination of the rate of turnover from the experimental data, a correction has to be applied. Since it is not practical to occlude the first carotid artery for more than a few hours, the first eye may not have reached its new equilibrium concentration by the

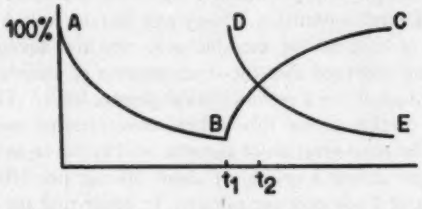

Chart 1.—Method for determination of rate of turnover of ascorbic acid in the aqueous.

time the clamp is shifted. Taking this into account and assuming all curves to be simple expotentials with the same rate constant, k, the time of intersection, t_2, is related to the other factors of the experiment by the equation:

$$2 \cdot e^{-k\ (t_2 - t_1)} = 1 + e^{-k \cdot t_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Fourteen male albino rabbits weighing between 2 and 2.5 Kg. were used. The animals were kept under intravenous urethan anesthesia (1.5 Gm. per kilogram of body weight) in a room maintained at 30 to 31 C. during the experiment. They were given 10 mg. of heparin per kilogram of body weight intravenously after surgical exposure of the carotid arteries. The right carotid artery was clamped for 180 minutes (t_1) with a rubber-covered clamp. At the end of this period the clamp was removed and the left carotid artery was tied. There was immediate pulsation of the right carotid artery distal to the previous site of the clamp. At time intervals varying from 30 to 90 minutes following the occlusion of the left carotid artery, samples of aqueous were taken from both eyes simultaneously. The eyes were proptosed, and the topical anesthetic was applied. The aqueous humor was immediately placed in small, weighed tubes containing 5 per cent metaphosphoric acid. The amount of aqueous was determined by weight difference, and ascorbic acid was titrated with dichlorophenolindophenol. An Agla micrometer syringe was used for the titration, and adequate mixing was secured by magnetic stirring. Three determinations were made on each sample, and the middle value was used. The three values usually agreed to within a few per cent.

5. Linner, E.: A Method for Determining the Rate of Plasma Flow Through the Secretory Part of the Ciliary Body, Acta physiol. scandinav. **22**:83, 1951.

Ascorbic Acid Values in Eyes of Rabbits at Various Intervals After Release of First Carotid Artery and Occlusion of Second

Rabbit No.	Time t-t_1, Min.	Ascorbic Acid, Mg./100 Cc.		Ratio L/R
		Left Eye	Right Eye	
55	30	21.4	19.4	1.10
56	30	15.6	14.0	1.11
60	40	23.1	22.0	1.05
61	40	41.1	40.3	1.02
62	50	14.9	15.1	0.99
63	50	29.5	29.1	1.01
64	60	16.5	17.4	0.95
65	60	19.9	21.0	0.95
57	60	34.2	25.6	0.95
58	60	27.4	29.5	0.93
66	70	22.5	24.3	0.93
67	70	31.9	34.8	0.92
53	90	28.2	30.6	0.86
54	90	20.6	23.7	0.87

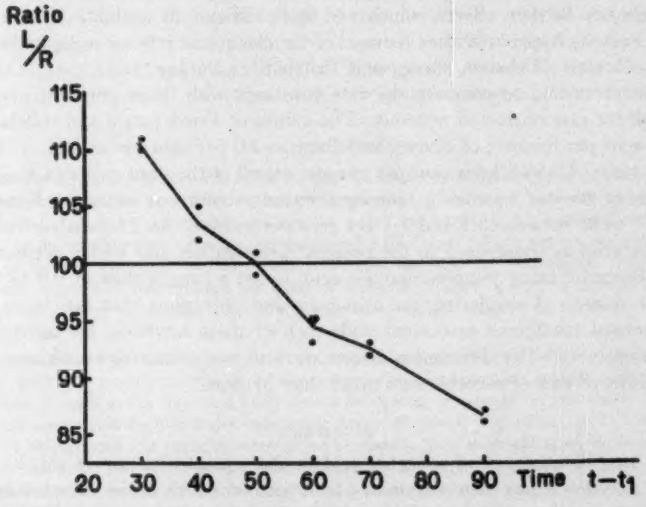

Chart 2.—Ratios of ascorbic acid level in the left eye to that in the right eye after release of the first carotid artery and occlusion of the second.

RESULTS

The accompanying table shows the ascorbic acid values obtained in the two eyes at various time intervals after release of the first carotid artery and occlusion of the second. In order to determine the time when the two eyes have the same concentration of ascorbic acid, the ratios of left eye to right eye were plotted against time, in minutes, after shifting the clamp. From chart 2 it is seen that after 45 to 50 minutes both eyes have reached the same ascorbic acid level, and thus the ratio 1.0 is obtained. This, then, is $t_2 - t_1$, and an approximate measure of the half-life of ascorbic acid in the rabbit aqueous.

If the value 45 to 50 for $t_2 - t_1$ is inserted into equation 1, one obtains values for the rate constant of 1.45 to 1.29 per cent per minute, or half-lives of 48 to 54 minutes.

COMMENT

Several criticisms can be raised against the values obtained in the above manner. One factor which would play a part is diminished rate of flow of aqueous after the carotid artery is clamped. In a small number of experiments, Barany [6] found that the turnover rate of radioactive sodium was about 7 per cent lower on the side of a closed carotid artery. Since sodium seems to leave the anterior chamber mainly by flow (Kinsey and Barany [2]), one would expect a similar figure to hold for the rate of flow of aqueous. A similar reduction would then be expected in the rate of turnover of ascorbic acid, since diffusion seems to play but a small part in the turnover of this substance. Thus, the rate constant of the falling part of the curve in chart 1 (*AB* and *DE*) will be only about 93 per cent of normal. If one applies this correction, equation 1 becomes slightly more complicated, but the results differ only by 3 per cent from those arrived at without the correction. The normal half-life then becomes 46 to 52 minutes, and the rate constant, 1.50 to 1.33 per cent per minute.

There are further effects, which are more difficult to evaluate. These would include reactive hyperemia after removal of the clamp and reflex closing and opening up of collaterals (Eckstein, Gregg and Pritchard [7]; Barany [8]).

It is interesting to compare the rate constants with those obtained previously and with the rate of flow of aqueous. The values of Friedenwald and collaborators, 0.8 per cent per minute; of Kinsey and Barany, 1.0 per cent per minute, and of the present study, 1.3 to 1.5 per cent per minute, are all of the same order of magnitude. The rate of flow of aqueous in nonanesthetized rabbits was found by Kinsey and Barany [2] to be between 1.1 and 1.3 per cent per minute. In 23 Swedish rabbits of the same kind as those used in the present investigation and under urethan anesthesia, Barany,[9] using *p*-aminohippuric acid, found a rate of flow of 0.9 to 1.0 per cent per minute. Considering the criticisms and objections that can be raised to the abnormal conditions associated with each of these methods, the agreement is quite satisfactory. The differences do not warrant one's drawing conclusions about mechanisms of exit of ascorbic acid other than by flow.

SUMMARY

The rate of turnover of ascorbic acid in the aqueous humor of rabbits under urethan anesthesia has been determined by a method which utilizes the fall and rise in ascorbic acid following alternate occlusion of the carotid arteries. The values obtained were 1.3 to 1.5 per cent per minute.

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6. Barany, E. H.: Influence of Intra-Ocular Pressure on the Rate of Drainage of Aqueous Humour: Stabilization of Intra-Ocular Pressure or of Aqueous Flow? Brit. J. Ophth. **31**:160, 1947.

7. Eckstein, R. W.; Gregg, D. E., and Pritchard, W. H.: Magnitude and Time of Development of Collateral Circulation in Occluded Femoral, Carotid and Coronary Arteries, Am. J. Physiol. **132**:351, 1941.

8. Barany, E. H.: Influence of Local Arterial Blood Pressure on Aqueous Humour and Intra-Ocular Pressure: An Experimental Study of the Mechanisms Maintaining Intraocular Pressure; Intraocular Pressure and Local Blood Pressure from Seconds to Hours After Unilateral Carotid Occlusion; Research for Homeostatic Reflexes in Undisturbed Eye, Acta ophth. **24**:337, 1946.

9. Barany, E. H.: Influence of Some Factors on Rate of Flow of Aqueous Humour, Proceedings of the Eighteenth International Congress of Physiology, 1950, p. 85.

AUREOMYCIN IN THE TREATMENT OF TRACHOMA

RENALD CHING, M.D.*
HONG KONG

THERE have been a number of recent favorable reports on the use of aureomycin in ophthalmology. The claim that it is a specific drug against many virus diseases naturally leads to the question whether it is equally efficacious in the treatment of trachoma, a disease which many authorities now believe belongs to the group of virus infections. Cases of trachoma make up over 50 per cent of all ophthalmic cases in the charity hospitals of this city. With such an abundance of clinical material at hand, I have taken advantage of the offer of the Lederle Laboratories Division, American Cyanamid Co., New York, to use its free supply of aureomycin for a study of the effect of this drug on a series of selected trachoma patients.

PLAN OF STUDY

We usually do not hospitalize trachoma patients no matter how serious their condition. They are treated and operated on in the outpatient department. The ward beds are reserved for patients with other, more serious diseases and for major eye surgery. An exception was made, however, by designating four beds for the purposes of this study. Each patient occupied a bed 15 days or so and was then told to return at certain intervals for observation. Over seven months was required to run through the study of some 60 patients. I made it a point to select patients with serious conditions, especially those who needed surgical care, to justify their occupying a bed.

The nurse was instructed to put 1 drop of aureomycin hydrochloride solution into each eye at hourly intervals, exactly on the hour, when the patient was awake. A patient thus got 12 or 13 drops in each eye a day, and each time a recording was made on the chart. A fresh solution of aureomycin hydrochloride was made every 48 hours, and when not in use it was kept in the refrigerator. If capsules were given by mouth, they were administered twice daily, at 8:00 a. m. and 8:00 p. m., each capsule containing 250 mg. of aureomycin hydrochloride. This medication was continued even if surgical treatment was carried out.

The aureomycin solution for ophthalmic use was made by adding 5 cc. of distilled water to the dropper bottle.[1] On several occasions when I ran out of this form, I opened a 250 mg. capsule of the aureomycin hydrochloride and made up a 0.5 per cent solution by adding distilled water. This is not recommended by the manufacturer, but, except that the preparation was less soluble in the cold and tended to deposit a yellow powder in the fornix, it offered no disadvantage. I noticed no irritating effect and received no complaint from any of the patients. As far as I can see, the efficacy of the ophthalmic solution and that of the unbuffered aureomycin hydrochloride solution are the same.

I divided the patients into three groups: Group I was given both drops of the ophthalmic solution and capsules; group II, only drops, and group III, only capsules. These patients were

* Ophthalmologist to Tung Wah East Hospital.

1. Each vial with dropper contains 25 mg. of aureomycin hydrochloride, 62.5 mg. of sodium chloride and 25 mg. of sodium borate. To this, 5 cc. of distilled water is added to make a solution for ophthalmic use.

TIME	TYPE AND DEGREE	PANNUS	VISION	OTHER CONDITIONS AND COMMENT
Group I (12 cases): Ophthalmic aureomycin solution drops, 0.5% q.h., plus aureomycin hydrochloride capsules, 250 mg. b.i.d. orally				
Case 4 (A1675): M: 44: Kahn +				
1	Gelat.-cicatr. ++++ | ++++ / ++++ | ++++	+++ +++	R:HM at 0.3 M. L:6/18	OD:Shallow ulcer; ant. chamber and pupil invisible OU:Entropion +++ | +++ / - | - Active inflammation and tearing, OD > OS
3	. .	. .	R:CF at 0.16 M. L:6/18	OU:Hotz operation
6	++++ | ++++ / +++ | +++	+++ +++	R:CF at 0.6M. L:6/60	Decrease in vision unexplained
13	. .	OS:thinner ?	R:CF at 1 M. L:6/24	OD:Clearing; ulcer healing and becoming a facet
16	+++ | +++ / ++ | ++	++ ++	R:6/60 L:6/18	OD:Ulcer healed smoothly with thin scar Discharged
30	+++ | +++ / ++ | ++	++ ++		OU:Quiet and clean; lids in good position
Case 7 (A1681): M:42: Kahn ++				
1	Pupill.-gelat. ++++ | ++++ / +++ | +++	+++ +++	R:6/18 L:6/24	OU:Injection bulbar conjunctiva; pannus infiltrates; moderate amount of secretion
2				OU:Less stippling and less injection
5	++ | ++ / ++ | ++	++ ++	R:6/6- L:6/6	OU:Clean; stippling gone
7			R:6/9 L:6/6	Discharged vs. advice
14	Fine pupill. ++ | ++ / ++ | ++	+ +	R:6/6 L:6/6	OU:Clean and quiet
Case 8 (A1735): M: 37				
1	Cicatr. ++++ | ++++ / ++++ | ++++	++++ ++++	R:CF at 2 M.- L:No CF	OU:Total corneal opacities; posterior symblepharon; ant. chamber and pupil barely visible; entropion
2				Hotz operation on right upper and left upper and lower lids
6	. .	. .	R:CF at 2 M. L:CF at 10cm.	OU:Quiet; opacity clearing; pupil becoming visible
16	+++ | +++ / ++ | +++	+++ +++	R:CF at 2 M L:CF 0.3 M.	OU:Clean and quiet; lids in good position Discharged
28	+++ | +++ / ++ | ++	+++ +++	R:CF at 2.5 M. L:CF at 0.3 M.	
6 wk.	+++ | +++ / ++ | ++	+++ +++	R:CF at 2.5 M. L:CF at 0.3 M.	OU: anterior chamber and pupil visible
Case 12 (A1829): F: 50: Kahn +				
1	Gelat.-cicatr. ++++ | ++++ / ++++ | ++++	+++ +++	R:6/60 L:CF at 1 M.	OU:Ptosis; severe inflammatory symptoms, more in OS OS:Deep-staining ulcer
3				OU:Quieting down; OS:Ulcer disappearing
7	+++ | +++ / ++ | ++	+++ +++	R:6/60 L:CF at 1.6 M.	OS:Non-staining facet
15	+++ | +++ / ++ | ++	++ +++	R:6/18 L:6/60	OU:Quiet; OS:Thin cicatrix left Discharged from hospital
25	+++ | +++ / ++ | ++	++ +++	. .	OU:Quiet
60	+++ | +++ / ++ | ++	++ +++	. .	OS: Thin cicatrix (macula); mild circumcorneal injection

Chart 1.

(See legends on opposite page)

given aureomycin for five consecutive days, followed by five days of withdrawal, but with the substitution of 0.25 per cent zinc sulfate, and then five days of aureomycin therapy. No other medication was given.

At the end I added two groups as controls. In one (group IV), for the borate-buffered aureomycin solution I substituted a 10 per cent sodium sulfacetimide solution, and in the other (group V), penicillin, 1,000 units per cubic centimeter; both solutions were administered as drops, and under the same conditions as the aureomycin preparations. The results in these control groups, though the patients were few, lead to interesting conclusions.

All patients admitted were given a complete physical examination and a routine blood cell count and urinalysis. Only significant findings are noted in the case reports. Patients who were seropositive for syphilis were not treated for this disease until they were discharged.

Fifty-seven patients were followed through the routine of the experiment. All were Chinese, and mostly of the poorer type, who visit our charity hospitals. For conservation of space, only representative cases will be reported from each group. The total number of patients is stated for each group.

COMMENT

It was shown that aureomycin hydrochloride had a marked beneficial effect in all the cases in which the drug was employed. It mattered not in what form it was given—as the borate-buffered, ophthalmic solution or as the unbuffered aureomycin hydrochloride solution; or as drops alone or orally or by the combined method—general good results were immediately noticed.

According to the table, in which the results of treatment are summarized, the combined local and systemic administration appeared to give a higher percentage of good results and more rapid improvement. The improvement in the groups receiving penicillin and sodium sulfacetimide was a bit slower. I believe this improvement was due to elimination of secondary infection and that the fundamental characteristics of trachoma remained. The point is not which drug or method is most effective but whether the drug in question is or is not specific against trachoma itself.

The severer the inflammatory condition of the eye, the more dramatic was the result. Corneal infiltration, ulcers and abscess with hypopyon, with their accom-

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Explanation of Chart 1

Chart 1.—Summary of cases 4, 7, 8 and 12.

In this chart, and in charts 2, 3 and 4, the following symbols are used:

In the left hand column, the number of days (unless otherwise indicated) or weeks after aureomycin therapy was started in the hospital is indicated by numerals. *1* is the day of admission and the first day of aureomycin therapy; *3*, the third day, etc.

In the next column, the cross is used to separate the upper and lower and the right and left lids: $\frac{\text{R upper}}{\text{R lower}} \Big| \frac{\text{L upper}}{\text{L lower}}$. The type of trachoma, such as follicular, papillary hypertrophy and gelatinous-cicatricial, in abbreviated form, is indicated above this cross.

Plus signs are used to designate the amount and severity of involvement of the lids, as follows: +, lesion limited to fornix; + +, lesion extended outside fornix; + + +, lesion extended to more than half the lid conjunctiva, but leaving marginal strip clear; + + + +, lesion involving whole lid, leaving no normal conjunctiva.

The amount and severity of pannus are indicated as follows: +, slit lamp observation of stippling and minute vessels in the upper limbus; + +, that seen by aid of the 10 X loupe and focal light; + + +, that seen with the naked eye, but which may cover as much as half the cornea; + + + +, that involving three fourths to the whole surface of the cornea.

HM indicates hand movements; CF, counting fingers.

+ indicates early entropion with slight trichiasis; + +, entropion with less than half the lashes turned in; + + +, entropion with more than half the lashes touching the cornea; + + + +, a boat-shaped deformity of the tarsus with all lashes turned inward.

TIME	TYPE AND DEGREE	PANNUS	VISION	OTHER CONDITIONS AND COMMENT
Group II (24 cases): Ophthalmic Auromycin Hydrochloride Solution 0.5% drops only q.h.				
Case 13 (1813): M: 47				
1	Gelat.-cicatr.		R:6/60 L:6/12	 OD:Deep-staining, progressive ulcer; acute symptoms OS:Quiet; pterygium
3				OD:Ulcer filling in; less staining; milder symptoms; still tearing
5			R:6/18 L:6/12	OD:Nonstaining facet left
10			R:6/12 L:6/9	OD:Quiet; thin macula
13			R:6/9 L:6/9	Discharged from hospital
20			R:6/9 L:6/9	
Case 18 (A1888): M: 43				
1	Gelat.-cicatr.		2:CF at 0.3 M. L:6/18	 OD:Large corneal abscess; severe inflammatory signs; anterior chamber deep, empty; ectropion due to large healed maxillary defect from osteitis after tooth extraction 10 yr. ago OD:Quiet
2				OD:Abscess smaller and clearing
5			R:CF at 0.6 M. L:6/12	OD:Pupil visible
10				OD:Nonstaining facet
3 wk.			R:CF at 2 M. L:6/12	OD:Leucoma left
½ mo.				OD:Quiet, clean
Case 34 (B200): F: 34; Kahn +++				
1	Cicatr.		R:6/60 L:6/36	 OU:Syphilitic keratitis; irregular, faint staining corneal infiltrates OU:Dilation with atropine; tearing profuse
5			R:6/24 L:6/36	OU:Tearing much less; cornea clearer? OD:Faint stain; OS:Nonstaining facet
3 wk.			R:6/18 L:6/18	OU:Quiet; cornea clearing up Discharged from hospital
5 wk.			R:6/18 L:6/18	OU:Quiet; faint scarring left; antisyphilitic treatment begun
Case 35 (B218): F: 58				
1	Gel-cicatr.		R:CF at 2 M. L:LP	 OU:Thick conjunctival discharge; anterior chamber and pupil true OS:Ulcer of cornea deep staining; abscess forming
3				OU:Symptoms relieved OS:Abscess gone; ulcer cleaner, less deep staining
5			R:CF at 5 M. L:CF at 1.5 M.	OS:Quiet; small denuded area left; still ciliary injection
2 wk.			R:6/18 L:CF at 1.5 M.	OS:Non-staining facet
2 mo.			R:6/18 L:6/24	Discharged from hospital

Chart 2.—Summary of cases 13, 18, 34 and 35.

TIME	TYPE AND DEGREE	PANNUS	VISION	OTHER CONDITIONS AND COMMENT
Group III (8 cases): Aureomycin hydrochloride capsules, 250 mg. b.i.d. orally only				
Case 38 (A2009): M; 13; Kahn ++; saddle nose deformity				
1	Beefy ++++ | ++++ / +++ | ++++	+++ +++	R:6/18 L:6/18	OU:Entropion +++ | ++ / + | + OU:Tearing and blepharospasm
3				OU:Lids opened; tearing
11	+++ | ++ / +++ | ++	+++ +++	R:6/18 L:6/18	Still tearing
18	Less beefy +++ | ++ / +++ | ++	+++ +++		Antisyphilitic treatment started; kept in hospital OU:Sodium sulfacetimide 10% q.h.; tearing
1 mo.	Much less beefy			OU:Notz operation on upper lids
1½ mo.	Smooth +++ | +++ / +++ | ++	+++ +++		No tearing; discharged from hospital
2½ mo.	+++ | +++ / +++ | ++	+++ +++	R:6/36 L:6/12	OU:Corneal clear; GPD Rx sodium sulfacetimide 10% q.h.
5½ mo.	Smooth +++ | +++ / +++ | +++	+++ +++	R:6/18 L:6/12	OU:Quiet; OD:Leukoma left
Case 41 (844): M; 36; Kahn +				
1	Cicatr. +++ | +++ / +++ | +++	++ +++	R:6/12 L:LP	OD:Quiet OS:Large ulcer; deep stain; anterior chamber and pupil invisible; marked inflamatory symptoms; lids closed tightly
2				OS:Staining area smaller;can open lids well; injection still marked
5			L:CF 0.3 M.	OS:Pupil visible; Still inflamed
13	+++ | +++ / +++ | +++	++ +++	R:6/12 L:CF at 2 M.	OS:Nonstaining;faint macula left Discharged from hospital
Case 42 (847): M; 35; Kahn ++				
1	Papillary ++ | ++ / ++ | ++	++ +++	R:6/36 L:6/24	OD:Posterior synechia; esotropia 45°; quiet OS:Deep-staining ulcer; anterior chamber and pupil free; inflamatory symptoms
3	. .	. .	. .	Regressing;slight stain
7	++ | ++ / ++ | ++	++ +++		OS:facet;nonstaining
11				OD:Squint operation OU:Immediately parallel
1 mo.	++ | ++ / ++ | ++	++ +++	R:6/36 L:6/24	OU:Quiet
3½ mo.				OD:Undercorrection 15°
6 mo.	++ | ++ / ++ | ++	++ ++	R:6/24 L:6/18	OU:Quiet
Case 43 (865) F 25				
1 day	Gelat.-cicatr. ++++ | ++++ / +++ | +++	+++ ++++	R:CF at 2 M. L:CF at 0.5 M.	OU:Entropion +++ | +++ / + | + OS:pupil barely visible OU:Blepharitis ciliaris OU:Notz operation upper lids
2 day				
7 day				OU:Blepharitis subsiding
14 day	++++ | ++++ / +++ | +++	+++ ++++	R:CF at 1½ M. L:CF at 1½ M.	OU:Still some blepharitis
16 day	. .	. .		OU:Starting aureomycin drops 0.5% q.h.
18 day	. .	. .	R:CF at 1½ M. L:CF at 1½ M.	OU:Better Discharged from hospital
30 day	+++ | +++ / +++ | +++	++ ++		OU:Quiet; lids good position
3½ mo.	+++ | +++ / +++ | +++	+++ +++	R:CF at 1½ M. L:CF at 1½ M.	OU:Moist OD:Few ingrowing eyelashes

Chart 3.—Summary of cases 38, 41, 42 and 43.

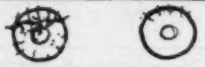
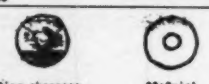
TIME	TYPE AND DEGREE	PANNUS	VISION	OTHER CONDITIONS AND COMMENT
Group IV (8 cases): Only sodium sulfacetimide 10% q.h. under same conditions				
Case 48 (8372): M; 28				
1d	Papillary		R:CF at 0.75 M. L:6/26	 OU:Entropion OU:Mucoid secretion; eczematous blepharitis
5d			R:CF at 1.25 M. L:6/26	OD:Clearer OU:Blepharitis gone; lids still moist
7d			R:CF at 2 M. L:6/26	
11d			R:CF at 2 M. L:6/26	OU:Clean; quiet Discharged from hospital
Case 50 (8336): M; 41				
1d	Gnlat.-cicatr.		R:CF at 1.5 M. L:6/60	 OU: Dense corneal opacities; anterior chamber and pupil free OU: No symptoms
2d				OD:Optical iridectomy at 11 o'clock
7d			R:CF at 3 M. L:6/36	
14d			R:CF at 3 M. L:6/36	OU:Quiet OD:Clear colobona; OS:Leukoma adherens left Discharged from hospital
5 wk			R:CF at 3 M. L:6/36	
Group V (5 cases): Only penicillin drops, 1,000 units/cc. q.h. under same conditions				
Case 55 (8548): M; 38				
1d	Intense red		R:No CF L:6/9	 OD:Ring abscess; hypopyon; miserable condition OS:Quiet
3d				OD:Clearing; less hypopyon
6d				OD: Nonstaining facet
8d			R:CF at 0.3 M. L:6/9	OD:Quiet; clearer
15d				OD:Hypopyon all gone; pupil visible
20d				OD:Facet left; anterior synechia (no atropine used throughout);mild circumcorneal injection; discharged from hospital
Case 56 (8567): M; 18; Kahn ++				
1d	Papill.-cicatr.		R:6/18 L:CF at 0.6 M.	 OU:Entropion OU:Thick mucoid secretion OD:Macula; OS:anterior chamber and pupil barely visible
3d				OU:Less secretion
5d			R:6/12 L:CF at 2 M.	OD:Clean and pale; OS:Pupil becoming visible
10d				OU:Motz operation on upper lids
21d			R:6/12 L:CF at 4 M.	OU:Clear and quiet; lids in good position

Chart 4.—Summary of cases 48, 50, 55 and 56.

panying symptoms of tearing, redness, discharge, blepharospasm and misery, all regressed in a matter of hours and disappeared in a matter of days (cases 7, 12, 13, 18, 35, 41 and 42). Vision correspondingly improved. This good effect continued after the patient's discharge from the hospital. I have kept some patients under observation up to five or six months. Some patients failed to come back, and some returned only once or twice shortly after discharge. However, it is my belief that up to the time of this writing the majority of cures have been permanent. I have

Summary of Results of Treatment of Trachoma with Aureomycin and Other Agents

Treatment	Total No. Patients	Percentage of Observed Eyes				
		Lids	Pannus	Vision*	Redness and Discharge	Acute Corneal Infiltration or Ulceration
Group I: Aureomycin Locally and systemically	12					
Improved	..	17	8	22	100	100
Moderately improved	..	62	58	16	...	...
Unimproved	..	21	34	52	...	...
No. of eyes with observed symptom	..	24	24	24	8	4
Group II: Aureomycin Locally	24					
Improved	..	7	2	35	89	71
Moderately improved	..	41	32	27	11	...
Unimproved	..	52	66	38	...	29
No. of eyes with observed symptom	..	46	44	37	19	7
Group III: Aureomycin Orally	8					
Improved	..	..	17	13	...	100
Moderately improved	..	31	17	33	100	...
Unimproved	..	69	66	54	...	...
No. of eyes with observed symptom	..	16	12	15	4	2
Group IV: Sulfacetimide Locally	8					
Improved	..	12	..	8	63	100
Moderately improved	..	19	30	15	37	...
Unimproved	..	69	64	77	...	...
No. of eyes with observed symptom	..	16	14	13	8	3
Group V: Penicillin Locally	5					
Improved	..	..	11	..	71	100
Moderately improved	..	20	33	14	29	...
Unimproved	..	80	56	86	...	...
No. of eyes with observed symptom	..	10	9	7	7	1

* "Improved vision" means improvement of two lines or more on the Snellen chart; "moderately improved vision," improvement of one line on the Snellen chart.

not yet seen a recurrence of inflammation, and patients of this type usually come back if there is one.

On the other hand, when the eyes were quiet and there were no inflammatory symptoms to begin with, the pathological picture of trachoma was not much changed by aureomycin. The gelatinous follicles and papillary hypertrophy at the beginning cleared up a bit; the pannus became thinner, and the vessels even became ghostlike. But this was the result of removal of a secondary infection and inflammation coexisting with the trachoma. The fundamental characteristics of trachoma remained and could not be mistaken on examination. Even syphilitic complications seemed to disappear rapidly, but the lesions of trachoma were left behind (case 34). It may

be said that the observation time was too short and that what I am observing is no longer active trachoma, with a living virus, but the scars and dead tissue left behind by trachoma. It is true that a longer period is required to see whether there is any further change in the pathological process, and laboratory investigations should be made to corroborate a clinical observation of this kind.

This study so far does not lend support to the statement that aureomycin is specific against trachoma. The drug is a good antibiotic against staphylococci, streptococci, pneumococci and other bacteria that invade the soil prepared by trachoma. The present series of cases, which may be classified under "severe trachoma, with complications," illustrate this clearly. Another series, of a milder, "symptomless, noncomplicated type of trachoma," also confirms this belief. I did not include cases of this type in the present report because the patients were not hospitalized and I could not be sure that conditions of treatment were uniform. They were private office patients who were picked up by emigration authorities for compulsory treatment of trachoma before tickets could be issued for passage abroad. This type of trachoma has an area of papillary hypertrophy in the upper fornix and a thin pannus, observable with a 10 × loupe. The patients were of a better class. There was no complication, and they were not aware of any symptoms. I doubt whether this type of trachoma, in the absence of secondary infection, will ever be transformed into the severe kind. Aureomycin was given these patients, with full instructions to use the drug at home. Most of them showed no effect and failed to pass the examining physician after two months of continuous treatment.

This experiment, incidentally, again raises the question whether there is such a thing as acute trachoma, whether trachoma per se causes blindness and whether complications of trachoma are but consequences of secondary inflammation, and in the absence of such complications trachoma is a harmless disease. These problems are academic. In our clinic we take both trachoma and its terrible sequelae in our stride, with no thought that the two can be considered separately. In the therapy of trachoma we must stop and ask: Are we satisfied with having a "shotgun" to knock off all secondary invaders, or must we continue to look for the specific agent against the virus? Which problem is the more important?

The few cases in groups 4 and 5 were used as controls by substituting for the aureomycin, respectively, sodium sulfacetimide 10 per cent and penicillin 1,000 units per cubic centimeter, both given in the form of drops under the same conditions as aureomycin. It is my impression that one of the latter drugs is just as effective as the other against secondary inflammation and just as ineffective as the other against the virus of trachoma. This statement includes the sulfonamide drugs given by mouth, if I may draw from experience in cases of trachoma outside this series. It may explain the conflicting reports on the use of the sulfonamide drugs in treatment of trachoma a few years ago. Then, we may also include the old stand-bys, such as silver nitrate, copper sulfate, zinc sulfate and quinine, since they have about the same action on trachoma, with the same lasting effect, if they are used frequently and long enough. We have, therefore, a wide choice of therapeutic drugs. The antibiotics are more rapid in their actions and less painful. The antiseptics are also mild cauterants, or astringents, producing slow, fine cicatrization, which is still the criterion of cure of trachoma. Both groups of drugs are useful, and one cannot replace the other.

SUMMARY AND CONCLUSIONS

Data on a series of 44 selected trachoma patients hospitalized for aureomycin treatment are tabulated to show the effect of the antibiotic. Under similar conditions, eight patients were treated with 10 per cent sodium sulfacetimide, and five, with penicillin 1,000 units per cubic centimeter, as controls. This study shows that trachoma itself and the complications due to a host of secondary organisms are two separate entities. Aureomycin has no effect on trachoma. Like a blunderbuss, it knocks out all the secondary organisms, including syphilis, in record time, and the effect lasts at least several months after the patient is discharged from the hospital. This experiment cannot refute the claim that aureomycin may have a destructive effect on the trachoma virus, but for verification in one way or the other, further clinical and laboratory investigations must be made. If elimination of secondary inflammation means that trachoma is left a harmless disease of the eye, then, indeed, by our clinical concept, trachoma is cured. Aureomycin, like sulfonamide drugs, penicillin and the antiseptics, is a valuable addition to our armamentarium for the therapeutics of trachoma.

Asia Life Building, 14 Queen's Road C.

PLATINUM IMPLANT IN GLAUCOMA SURGERY

WILFRID E. MULDOON, M.D.
PAUL H. RIPPLE, M.D.
SAN ANTONIO, TEXAS
AND
HELENOR CAMPBELL WILDER
WASHINGTON, D. C.

THIS PAPER describes the clinical and pathological observations on the use of intraocular platinum implants in rabbit eyes and reports on the use of a platinum wire seton in two human eyes with glaucoma. The idea of using a foreign body as a method of making a drainage tract for the flow of aqueous in glaucoma is not new.

Troncoso[1] in 1940, in an extensive article, reviewed the literature on intraocular implants. He reported his results on the implantation of magnesium experimentally in rabbit eyes and on the use of magnesium implants in 12 glaucomatous human eyes. The metal was inserted between the sclera and the ciliary body in the cyclodialysis operation with the object of preventing reattachment of the ciliary body to the sclera. His conclusions were as follows:

> There was at first a mild reaction to the foreign body, with numerous bubbles of gas appearing in the anterior chamber and under the conjunctiva. The reaction subsided in about a week, and the metal was entirely absorbed at the end of twenty days. Clinical results have been good in the majority of cases; in others, there was improvement of hypertension, and in 1 case no improvement occurred. The method is harmless and may be repeated several times in the same eye.

Ménégaux and Odiette,[2] in 1933 and 1934, published a number of articles on the effects of buried metals on bones and other tissues. They prepared "hanging drop" cultures of osteoblasts and fibroblasts from the heart, femur and tibia of chick embryos and from similar tissues of human embryos removed in cases of extrauterine pregnancies. Tiny pieces of metal were placed in the cultures and their effects on cellular growth observed. The authors found that all the metals used (copper, iron, magnesium, zinc, silver, tantalum, tin, nickel, tungsten and lead) interfered with the growth of the embryonal cells. Gold, aluminum and lead had no action on the fibroblast cultures. Copper and magnesium stopped all cellular growth, and iron showed marked inhibition of cell growth. The metals manifested toxicity in this decreasing order: zinc, silver, tantalum, tin, nickel and tungsten.

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1. Troncoso, M. U.: Cyclodialysis with Insertion of Metal Implant in Treatment of Glaucoma: A Preliminary Report, Arch. Ophth. **23**:270 (Feb.) 1940.

2. Ménégaux, G., and Odiette, D., cited by Venable, C. S., and Stuck, W. G.: The Internal Fixation of Fractures, Springfield, Ill., Charles C Thomas, Publisher, 1947, p. 27.

In 1937, Venable, Stuck and Beach [3] carried out extensive experiments on dogs to determine the effect on the tissues of metals implanted in bone. They noted not only the microscopic, but the histologic and roentgenologic, changes as well. Biochemical studies were made of the tissue, the exudates around the metals and the metals themselves. The authors demonstrated conclusively that all of "the metals commonly used in surgery were subject to electrolytic activity in body fluids" and that "the extent of tissue damage was roughly equivalent to the amount of galvanic action which took place." In the case of pure metals there is, of course, no galvanic action, and whatever action does take place is due to a chemical action of the body fluids on the metal. Some metals, such as gold and silver, are not actually in a pure state when they are used in surgery. Gold, for example, usually means 14 parts gold and 10 parts base metal. We could, therefore, expect an electrolytic effect. Likewise, sterling silver is 925 parts silver and 75 parts copper; so we could expect an electrolytic, as well as a chemical, reaction when such a metal is surrounded by body fluids. In the case of metals, the so-called foreign body reaction is not, as the name would imply, a protest on the part of the tissues to the mere presence of a foreign substance; it is an inflammatory reaction due to chemical or electrolytic activity in the metal, and in the absence of such activity there is no "foreign body reaction."

In the course of their experiments, Venable and associates found only one metal free from chemical and electrolytic activity in the human serum, and therefore completely inert in the body—an alloy named vitallium®.[4]

From the standpoint of innocuity, vitallium® would be the ideal substance to use as an ocular implant; unfortunately, it has physical characteristics which make it unsuitable for ocular surgery. It is not malleable or ductile and cannot, therefore, be bent into shape or be drawn into a wire; it must be cast in the size and shape in which it is to be used.

Pure platinum was chosen for use in the present investigation, for the following reasons: 1. Being an element, there would be no electrolytic reaction. 2. It is more inert chemically than any other commonly used metal, e. g., tantalum, which is rather soluble in weak organic body acids. 3. It is obtainable commercially in a pure state in wire of any desired diameter, from 0.002 inch up. 4. Although platinum is costly, the amount used is so small that a few cents worth would suffice for any ophthalmic operation.

1. RABBIT EXPERIMENTS USING PLATINUM WIRE IMPLANTS

In an effort to determine the tolerance of various ocular tissues to sterile platinum wire implants, the following experiments were undertaken. It must be borne in mind that the results obtained in the rabbit experiments do not insure similar results in human eyes, since there are basic differences in their tissue responses and aqueous physiology.

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3. Venable, C. S.; Stuck, W. G., and Beach, A.: Ann. Surg. **105**:917, 1937. Venable, C. S., and Stuck, W. G.: Surg., Gynec. & Obst. **76**:297, 1943.

4. Vitallium® is a product of the Austenal Laboratories, Inc., 224 East Thirty-Ninth Street, New York. Its approximate composition is cobalt, 65 per cent; chromium, 30 per cent, and molybdenum, 5 per cent.

A. Subconjunctival Space

A horizontal incision was made through the conjunctiva and Tenon's capsule about 10 mm. above the limbus in one eye of each of two rabbits. The posterior flap was dissected back, and a small, flat coil of 0.004 inch platinum wire was placed under the flap. The incision was closed with a running silk suture. A similar procedure was carried out on the opposite eye of each rabbit except that implantation of the wire was omitted. Five days later the sutures were removed. The rabbits were examined at intervals for seven months. The coil could be seen easily beneath the conjunctiva, and at no time could any reaction be observed.

AFIP Accession 299582.—*Implant beneath Tenon's capsule.*

Gross Pathological Study.—A coil of wire was embedded beneath Tenon's capsule in the region of the ora serrata. Cloudy exudate was present in the optic disk, and streaks of it involved the adjacent retina. There was irregular pigmentation of the fundus. The cortical lens fibers appeared somewhat opaque. The uveal tract was pigmented.

Microscopic Study.—There was slight lymphocytic infiltration of the conjunctiva at the limbus on one side, but no evidence of intraocular inflammation. Slight fibrosis and mild foreign body reaction were present around the site of the wire in the epibulbar tissue.

AFIP Accession 299583.—*Implant beneath Tenon's capsule* (albino rabbit).

Gross Study.—A coil of wire was embedded beneath the capsule in the region of the ora serrata. The coil was more extensive than that in rabbit 299582. The retina was opaque and slightly discolored beneath the membrane. A thick, opaque fold extended from the optic nerve forward into the retina.

Microscopic Study.—There was a very slight lymphocytic infiltration in the conjunctiva on both sides, but no evidence of intraocular inflammation. A small amount of fibrosis and a slight foreign body reaction with giant cell formation around the wire were present in the episclera.

B. Anterior Chamber

A single strand of sterile 0.004 inch platinum wire about 1 cm. in length was introduced, through hypodermic needles, into the anterior chamber of three albino rabbits. There was a very mild reaction, and in about three days a fine, feathery, white exudate (probably fibrin) was seen to form in a few patches on the wire. In another three or four days the exudate disappeared except where the wire was in contact with the angle or the base of the iris, where it fixed the wire with a small amount of connective-like tissues. The rabbits were examined at intervals for four months, during which time there were no more changes. The eyes remained quiet, and the anterior chambers were clear on slit lamp examination.

In one rabbit, the coil of wire was placed in the anterior chamber through a corneoscleral incision, which was closed with sutures. Again, there was mild reaction, and the coil became adherent to the iris with a small amount of connective tissue. The wound healed rapidly and completely, and the eye remained quiet for five months of observation.

AFIP Accession 299585.—*Wire in the anterior chamber.*

Gross Pathological Study.—There was a scar, apparently associated with a conjunctival flap, at the limbus. Extending from this scar to the cornea on the opposite side, and crossing the pupillary margin, was a straight piece of wire. The wire was hooked into the iris at both ends. The ciliary body appeared slightly thickened.

Microscopic Study.—A few lymphocytes and plasma cells were seen in the nictitating membrane. There was no evidence of intraocular inflammation.

AFIP Accession 299586.—*Wire in the anterior chamber.*

Gross Appearance.—There was a piece of wire in the pupillary area, which appeared adherent to the lens and cornea. The scar of introduction of the wire was not positively identified. On section, the wire was found not to be adherent to the cornea but did adhere to the iris and the lens.

Microscopic Study.—A few lymphocytes and plasma cells were seen in the conjunctiva, but there was no evidence of intraocular inflammation. A diagonal scar marking the introduction of the wire passed through the cornea. There were degenerative changes in the anterior cortical lens fibers.

AFIP Accession 299587.—*Coil of wire in the anterior chamber.*

Gross Appearance.—An opacity of the cornea occurred at the limbus. Beneath and central to this, a coil of wire was seen in the anterior chamber. The wire overlay the margin of the pupil, which was eccentric. There was an opacity of the lens in the pupillary area. The wire adhered to the iris.

Microscopic Appearance.—The iris was adherent to a wide scar of the cornea. The scar interrupted Descemet's membrane and was mildly infiltrated with lymphocytes, plasma cells and occasional eosinophils. On this side, there was a sparse scattering of lymphocytes and plasma cells in the iris and the ciliary body.

C. In a Cyclodialysis Tract

In one rabbit, a double strand of 0.004 inch platinum wire was inserted into a cyclodialysis tract, so that the doubled end was seen to protrude slightly into the anterior chamber. The two ends were coiled flat on the sclera, and the conjunctival flap was sutured over the coil. There was a moderate postoperative reaction, which subsided quickly; and the anterior chamber was clear during the five months of observation. The pupil remained round and showed no loss of function. A bleb formed over the coil and remained. There was no reaction at the site of the coil in the conjunctiva, and the coil could be seen clearly through the conjunctival covering. The coil showed no tendency to erode through the tissue, nor was there any proliferation of scar tissue at the site of the coil. A small cortical opacity formed in the lens.

AFIP Accession 299581.—*Cyclodialysis implant.*

Gross Appearance.—There was a bleb at the site of the limbal scar to which the wire adhered. The posterior cortical lens fibers were opaque. There were opacities on the surface of the iris and in the pupillary area. The iris, choroid and retina appeared opaque. There were also cloudy exudates in the retina. The wire adhered to the cornea at the limbus and appeared to be embedded in the iris. Sections showed fine wires in the ciliary body and the sclera at the equator. No melanin was seen in the uveal tract.

Microscopic Appearance.—Lymphocytes, plasma cells, many of which were binucleated, and occasional plasmacytoid cells infiltrated the filtration angle, limbus, iris and ciliary body. Mononuclear cells clung to the posterior surface of the cornea. Fibrinous exudate, containing lymphocytes, plasma cells and mononuclear cells, was present on the posterior surface of the iris, over the ciliary body and on the inner surface of the retina. The inflammatory reaction was particularly pronounced on the side which contained the wire.

D. Controls

AFIP Accession 299584.—*Incision in Tenon's capsule* (albino rabbit).

Gross Appearance.—There was a nodular scar in the region of the ora serrata. There appeared to be a slight opacity of the retina at the site of the operation, with a very small spot of discoloration.

Microscopic Appearance.—A few lymphocytes and plasma cells were seen in the conjunctiva on both sides. There was no evidence of intraocular inflammation. Just behind the ora serrata, on one side, was a calcified drusen on Bruch's membrane.

AFIP Accession 299588.—*Incision into the anterior chamber without an implant* (albino rabbit).

Gross Appearance.—The cornea and the anterior sclera were flattened on one side. There was a slight irregularity in the corneal margin, probably at the site of the scar. This was in the flattened area. There were minute pigmented areas at the equator (segment) and also in the region of the scar. Here the peripheral retina and the orbiculus ciliaris were thickened and opaque. On the opposite side, the retina was thickened and opaque posterior to the equator. The optic nerve appeared to have been pulled out when the eye was enucleated.

Microscopic Appearance.—A few lymphocytes and plasma cells were seen in the conjunctiva and, on one side, in the filtration angle and the ciliary body.

REPORT OF TWO CASES

Case 1 (fig. 1).—Mrs. C. M. L., a Mexican woman aged 48, had noticed failing vision in her left eye seven months previously. She consulted an ophthalmologist, who made a diagnosis of

glaucoma and had her use drops and ointment in both eyes. Vision in the left eye deteriorated rapidly and was lost completely. She had noticed some loss of vision in the right eye shortly before consulting me. Corrected vision in the right eye was 20/20 with ability to read Jaeger type 1; in the left eye it was nil. The intraocular tension was 25 mm. of mercury (Schiøtz) in the right eye and 53 mm. in the left eye. Visual field tests showed considerable enlargement of the blindspot in the right eye but otherwise nothing abnormal. The right optic disk showed physiological cupping, which extended to the temporal margin. The disk in the left eye was white with a deep, bowl-shaped cupping. There was no congestion or pain in either eye. The patient was given pilocarpine to use in both eyes, later supplemented with carbachol U. S. P. (carcholin®). Under this regimen, the tension in the right eye fluctuated between 23 and 30 mm. (Schiøtz). Visual acuity remained 20/20. The visual fields showed no loss until March 1944, when a large Bjerrum scotoma developed.

In April 1944, a sclerectomy with iridencleisis was done on the right eye. There was some bleeding into the anterior chamber, but convalescence was uneventful. Postoperatively, there was an elevation at the operative site filled with uveal tissue, but with only minimal bleb formation.

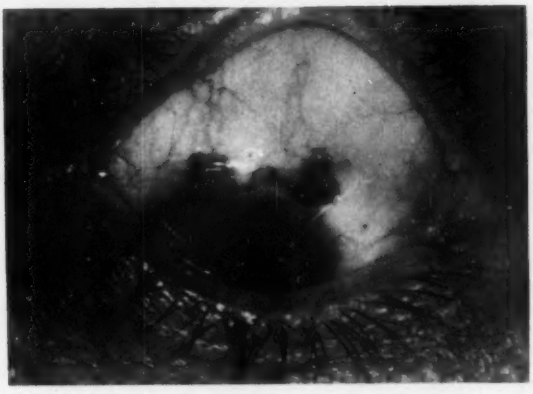

Fig. 1 (case 1).—To the right is the unsuccessful iridencleisis scar. On the left is the site of the seton operation, in which a flat coil of platinum wire was placed in a 4 mm. sclerotomy wound. Note the coil of wire in the center of the bleb.

During the next four years, she continued to use pilocarpine and carbachol in the eye. The tension was lower, varying from 15 to 21 mm. of mercury (Schiøtz), but, in spite of this, the field defects progressed; the Bjerrum scotoma became larger and encroached within 2 degrees of fixation and enlarged superiorly to blend with a large superior temporal defect in the periphery. In the meantime, a nuclear cataract developed, and there was increased cupping of the disk.

In an attempt to lower the tension further and to arrest the field changes, the following operation was performed in February 1948.

The conjunctiva was cut close to the limbus, just temporal to the site of the iridencleisis, between 10:00 and 12:00 o'clock, and was dissected back just enough to expose the limbus. Two double-armed 6-0 nonabsorbable surgical (silk) sutures were placed in the anterior limbus at 10:30 and 11:30 o'clock. Two millimeters behind the limbus, an incision about 4 mm. long was made in the anterior chamber with a keratome. A flat coil of four loops of platinum wire 0.004 inches in diameter was slid into the incision, part of it projecting into the anterior chamber and part lying outside the sclera. The two mattress sutures were then passed through the cut edge of the conjunctiva; the flap was drawn down over the wire, and the sutures were

tied in front of the incision. There was much less reaction from the operation than there had been from the previous iridencleisis. A good bleb formed over the wire.

Since the operation, the eye has been quiet, and the tension has stayed at about 18 mm. of mercury (Schiøtz). The lenticular opacities have progressed, however, so that distant vision has dropped to 20/200, but the patient can read Jaeger type 1 at 3 inches (7.5 cm.). The visual field has shown no further loss. At times the patient has a sensation of a foreign body under the upper lid where the lid rubs against the loop of wire. She uses no drops in the eye.

In April 1948 the blind (left) eye had to be enucleated because of painful absolute glaucoma.

CASE 2 (fig. 2).—Mrs. C. S. R., a Mexican woman aged 84, was first examined in July 1948. The right eye was completely blind from chronic, noncongestive glaucoma. The left eye had visual acuity of 20/80, and the visual field was limited to an oval area below fixation, 15 to 20 degrees in size, and to a small temporal island of vision. In the right eye there was a faint haze in the lens. The disk was white with a deep, bowl-shaped cupping. In the left eye, there was more haze in the lens, and the disk had a pale, pinkish tinge with a bowl-shaped cupping. Tension was 62 mm. of mercury (Schiøtz) in the right eye and 42 mm. in the left eye. The blood pressure was 190/100.

The patient was treated with carbachol and pilocarpine drops for six months, during which time the intraocular tension stayed at about 40 mm. of mercury in the left eye, never going

Fig. 2 (case 2).—A large bleb is seen at 12 o'clock over the site of the seton operation.

below 37 mm. (Schiøtz). There was further loss of visual fields, and the visual acuity dropped to 20/200.

In February 1949 the following operation was done, with use of local anesthesia:

The conjunctiva was cut close to the cornea between 11:00 and 1:00 o'clock; it was dissected back a few millimeters and allowed to retract. A double armed, 6-0 silk suture was placed in the anterior limbus. A groove about 6 mm. long was made 2 mm. behind and parallel to the limbus. A double strand of platinum wire, 0.002 inch in diameter, threaded on a small Kalt corneal needle, was passed into and immediately out of the anterior chamber through the floor of the groove. It was looped in and out of the anterior chamber in this manner four times, each loop being drawn up snugly. As the needle was passed in and out of the anterior chamber, a small amount of aqueous seeped out, but the anterior chamber did not empty. The free ends of the wire were cut close to the sclera, so that they did not project above the level of the groove. The conjunctiva was then drawn down, covering the groove, and was tied in this position with the preplaced mattress suture.

There was very little reaction from the operation and no postoperative pain. The patient was dismissed from the hospital on the fourth postoperative day. On the sixth day the anterior chamber was deeper than it had been before operation. There was a slight bulge at the operative site, and the platinum coil could be seen under the conjunctiva. The intraocular tension was 17 mm. (Schiøtz). Massage was instituted, and two weeks later the tension had dropped to 6 mm. One week later a good bleb had formed, which hid the wire from view. The tension has since remained between 12 and 17 mm. (Schiøtz); the visual acuity and visual fields have shown no further deterioration.

COMMENT

Clinically, the rabbit eyes showed little or no reaction to the platinum implants during a period of observation of from five to seven months. Pathological examination, however, revealed interesting changes, both gross and microscopic.

In all cases, except in that of the cyclodialysis implant, there was only a slight foreign body reaction around the wire and no evidence of intraocular inflammation.

Lenticular opacities were observed in several cases, not only those in which the wire was in contact with the lens but also in one of the cases of subconjunctival implant, in which there was no contact with the lens.

The rather severe pathological changes noted when the implant was placed in contact with the ciliary body seem to indicate that this region is an unfavorable site for an implant of any kind.

In the human cases, it should be noted that the wire implant was inserted at the limbus and was not in contact with the lens, iris or ciliary body, but had contact only with the sclera and conjunctiva. This location of the implant may have some bearing on the absence of clinical signs of inflammation.

The platinum wire used, even in the extreme fineness of 0.002 inch diameter, has considerable tensile strength and, if one is careful not to kink it, can be manipulated almost as easily as fine silk. The 0.004 inch wire is still more easily handled, but the increased bulk is a disadvantage.

On the basis of two cases, although the intraocular tension has been satisfactorily controlled for over two years, the operation is not recommended to supplant other operations for glaucoma, but the feasibility of the procedure, even after the failure of another type of operation, is demonstrated.

414 Navarro Street (Dr. Muldoon).

The experiments on rabbit eyes were performed by one of us (P. H. R.) in the animal experimental laboratories at the School of Aviation Medicine, Randolph Air Force Base, Randolph Field, Texas, under the supervision and with the aid of Col. Victor A. Byrnes. The pathological examinations and reports were made by Mrs. Helenor Wilder, of the Armed Forces Institute of Pathology.

NEW PLASTIC SURGICAL DRAPES

T. S. GERSPACHER, M.D.
H. D. FOWLER Jr., M.D.
AND
DAVID E. ROLF, M.D.
CLEVELAND

FOR THE most part, techniques used in ophthalmic surgery have been constantly improved over the past 20 years. But surgical draping has not kept pace—procedures and materials for draping have remained practically unchanged during the entire period.

Every ophthalmologist is fully aware of the problem presented in draping the orbital area: Because of the contour around the eye, difficulty is encountered in bringing the edge of the sterile field in close proximity to the operative site and in maintaining the sterile field in a fixed position during the surgical procedure. In an attempt at a solution, towel clips have been used to secure the drapes to the patient's skin. This, in turn, has further limited the already restricted area in which the surgeon must work. This problem of positive demarcation and fixation of the operative sites is not exclusively one of ophthalmic surgery. It is common to all surgery. Further, it is generally accepted that the very nature of the materials used for draping do not lend themselves to aseptic techniques. Cotton and linen, because of their absorbency, are not effective barriers against the passage of contaminating organisms from the skin surfaces.

In March 1948 one of us (T. S. G.), with Dr. Rolf and Dr. Fowler, of the Euclid Clinic Foundation in Cleveland, conceived the idea of a plastic surgical drape. It was felt that such an impermeable film would solve the problem of contamination caused by the use of absorbent cloth towels. In addition, a soft, pliable plastic film with good stretch characteristics could provide excellent conformability to the contours of the head.

With the problem of positive fixation of the sterile field in mind, the possibility of coating a pressure-sensitive adhesive on the plastic film was considered. This would seal the drape around the operative site and hold it firmly in place without the use of towel clips or other such devices.

Still another consideration was the unavailability of sterile drapes for surgery in the office or in the military field, where proper aseptic techniques are just as important as in hospital operating rooms. The office surgeon must operate his own sterilization equipment, order sterile linen from an outside supplier or simply use laundered linen towels. Worse still, the military surgeon on field duty often has

no source of sterile linen at all. It was decided that every surgeon, no matter where he had to operate, should have drapes at his disposal at all times which would conform to accepted standards of asepsis and remain sterile indefinitely.

The original idea of a plastic drape with pressure-sensitive adhesive was expanded, then, to include the sterile package principle.

A large manufacturer [1] of adhesives, because of the firm's extensive experience, was approached at this point. Research personnel of the firm, working in liaison with us, ultimately produced a drape which incorporated features that had been considered necessary to bring draping techniques up-to-date.

TYPES OF DRAPES

Four types have now been introduced to members of the medical profession. They include (1) the towel drape, measuring 7 by 16 inches (17.8 by 40.5 cm.); (2) the treatment drape, 16 inches square with a circular aperture in the center and (3) the perineal drape, which measures 16 by 26 inches (40.5 by 66 cm.). Each drape has an adhesive margin, placed so as best to demarcate the different possible operative sites. These three meet draping requirements for general and emergency surgery.

The fourth, the eye drape, was designed especially to meet the draping requirements of the ophthalmologist. Like the others, it is made of a thin plastic film, which is nontoxic and unaffected by most surgical antiseptics and solvents. The color is soft green, which tends to reduce glare and eyestrain. It measures 32 by 50 inches (81 by 127 cm.), with a 3 by 2 inch (7.5 by 5 cm.) elliptical opening in the center, which is bordered by the pressure-sensitive adhesive. The opening thus conforms easily to the orbital area and remains firmly in place, eliminating towel clips and resulting in much greater working freedom for the surgeon.

DESCRIPTION AND USE OF DRAPES

The drapes are packaged in an outer envelope of special aluminum foil laminated with plastic. The combination of these two materials makes an airtight wrapper that withstands rough handling. Within the outer package is a glassine-wrapped inner packet, which, in turn, contains another glassine packet protecting the drape itself. By the use of these two inner wraps the drape may be removed from the foil envelope with no danger of contamination. When the second inner package has been opened, with sterile precautions, a protecting paper liner covering the adhesive is stripped off and then the adhesive margin or edge is pressed down to adhere firmly around the eye and over the bridge of the nose. After the drape has been secured in position, it is unfolded. The drape is large enough to cover the entire head of the patient and can be extended over a Mayo stand; this creates an air space around the patient's face and enables him to breathe easily. From our trials, it was apparent that to have the drapes work most effectively it was necessary to dry the skin surface carefully with sterile gauze after it had been prepared in the usual manner.

1. The Minnesota Mining & Manufacturing Company.

Fig. 1.—Drape being adjusted to the orbital region.

Fig. 2.—Drape covering the patient's head and extending over a Mayo stand.

IRRITATION AND TOXICITY

The question of irritation of the skin and mucous membrane and systemic injury in animals has been studied by Love, Wright and Bieter in the department of pharmacology at the University of Minnesota.[2] The technique employed was largely that described by Draize, Woodard and Calvery.[3] Briefly, the results obtained by these investigators are as follows:

The surgical drape adhesive and the vinyl plastic film (drape material) were applied to the shaved skin of albino rabbits for periods up to 90 days. In no instance was irritation produced by the adhesive material. The same was true of the vinyl plastic film if aeration beneath a 3 by 5 inch (7.5 by 10 cm.) piece of film was allowed by holes punched in the film. When a solid piece of film was held in close approximation with rabbit skin, erythema and maceration of superficial skin layers began to occur on the seventeenth day of the test. If at this time aeration was provided, the skin rapidly returned to normal. During these tests no changes occurred in the blood and urine of the test animals, and gain in weight for all animals was normal.

The most interesting study on irritation was carried out on human skin. The new adhesive, the vinyl plastic film, and, for comparison, adhesive plaster U.S.P. and an adhesive plaster containing a fungicide were applied to the inner side of the forearm of a series of patients. For a single application lasting 48 hours, daily applications for 11 days and five applications over 21 days, respectively, the percentages of patients showing no reactions (normal skin) were as follows:

	48 Hr.	11 Days	21 Days
Surgical drape adhesive	72%	92%	43%
Vinyl plastic film	87%	85%	86%
Adhesive plaster U. S. P.	27%	0%	14%
Adhesive plaster containing a fungicide		8%	

The reactions observed consisted of itching, erythema and exfoliation. When these materials were applied repeatedly, the reactions became severer, so that most persons could not tolerate the two adhesive plasters for more than six days. The surgical drape adhesive, on the other hand, was tolerated by all subjects for the duration of the tests.

SENSITIVITY

Another series of experiments had to do with attempts to sensitize guinea pigs. Two weeks after an attempt to sensitize the guinea pigs only half of the animals showed any degree of sensitivity.

In our personal series of 500 surgical cases, including 300 ophthalmic cases, in which the operation lasted from 15 minutes to one hour, there was no evidence of irritation or sensitivity. The duration of application of the adhesive to patients' skins varied from 15 minutes to 4¼ hours. No evidence of irritation or intolerance was observed.

STERILITY

To assure sterility in the manufacture of these drapes, careful bacteriological studies were conducted by Dr. H. O. Halvorson and his associates at the University of Illinois.[4] They designed a system of complex laboratory controls with

2. Love, J. K.; Wright, H. N., and Bieter, R. N.: Personal communication to the authors.
3. Draize, T. H.; Woodard, G., and Calvery, H. O.: J. Pharmacol. & Exper. Therap. **82**:377, 1944.
4. Halvorson, H. O.: Personal communication to the authors.

heat-resistant organisms, such as PA 3679 and Bacillus stearothermophilus NCA strain 1,518, in order to assure absolute sterility. As a part of the manufacturer's standard controls on the drapes, bacteriological checks are made on each autoclave load before the drapes are released for distribution. All drapes are packaged under proper levels and are steam autoclaved for 40 minutes at 250 F. This period of sterilization exceeds normal requirements but assures a high margin of safety.

CONCLUSIONS

An important advantage we note in these new surgical drapes is that they are packaged sterile and ready for immediate use. This is particularly helpful when the ophthalmic surgeon does not have an autoclave available or there is inadequate nursing personnel. For these reasons, surgical drapes should be exceedingly useful in the military services, since for the first time the surgeon will have sterile drapes ready for instant use in the field. These drapes are strong enough to withstand almost any amount of handling and at the same time are light in weight and disposable after use. They clearly demarcate and seal off the operative site and form an impermeable barrier to moisture and fluids. These drapes are nontoxic and inert in character and may be removed from the skin without irritation. They easily drape the difficult orbital area because of their extreme conformability. In all, they offer ophthalmologists a more aseptic method of draping and greater freedom in the working area.

SUMMARY

The new plastic eye drapes described are available in sterile packages and ready for instant use. This is particularly helpful when the ophthalmic surgeon does not have an autoclave available or there is inadequate nursing personnel.

The drapes are economical and disposable.

Storage is a simple matter, because they will keep sterile indefinitely.

They are nontoxic and inert in character.

They enable the ophthalmic surgeon easily to drape an area which has heretofore been considered extremely difficult, namely, the orbital region.

The soft green color eliminates glare.

The operative site is clearly demarcated and sealed off.

The drapes eliminate soiling of clothes and towels.

They are nonabsorptive, in contrast to linen and cotton, and therefore act as effective barriers against the passage of contaminating organisms from the skin surfaces.

OCCLUSION OF CENTRAL RETINAL VEIN IN MIGRAINE

M. WALLACE FRIEDMAN, M.D.
LOS ANGELES

MIGRAINE is a symptom complex most commonly described as an intense recurrent headache, usually paroxysmal, usually unilateral, the outstanding features of which are the associated gastrointestinal and ocular symptoms. The usual visual disturbances accompanying migraine are premonitory and transitory flashes of brilliant spectral lights, followed by homonymous scotomas. Persistent ocular complications may be observed during all phases of the attack, various components of the eye being affected singly or in combinations. Oculomotor paralysis, the so-called ophthalmoplegic migraine, has been reported as occurring with and subsequent to the headache. Hemiplegia and hemianopsia have been found to persist after attacks of migraine,[1] but permanent visual disturbance is rare. The common ocular complications of migraine, together with the theories of their production, have been excellently reported by Donahue.[2]

REVIEW OF LITERATURE

There have been reports of permanent visual loss associated with retinal vascular changes after an attack of migraine. Galezowski (1882) first reported vascular spasm with migraine attacks. In his series of four published cases, thrombosis of the central retinal artery was present in two, thrombosis of the superior temporal branch in one and thrombosis of the peripheral retinal arteries in one.[3] Since that time there have been only 13 reported cases of retinovascular complications of migraine.

Occlusion of central retinal artery.....4 (resulting in blindness)[4]
Occlusion of central retinal vein.....1 (resulting in blindness)[5]
Occlusion of peripheral arterial branch.....7 (resulting in sector defects)[6]
Occlusion of intraneural branch of central retinal artery..1 (resulting in central scotoma)[7]

It is from this tabulation that only one case of occlusion of the central retinal vein as a complication of migraine has been reported in the literature.

1. Alpers, B. J.: Clinical Neurology, Philadelphia, F. A. Davis Company, 1946, p. 118.
2. Donahue, H. C.: Migraine and Its Ocular Manifestations, Arch. Ophth. **43**:96-141 (Jan.) 1950.
3. Cited by Graveson, G. S.: Retinal Arterial Occlusion in Migraine, Brit. M. J. **2**:838-840, 1949.
4. Grönvall, A.: On Changes in the Fundus Oculi and Persisting Injuries to the Eye in Migraine, Acta ophth. **16**:602-611, 1938.
5. Löhlein, W.: Erblindung durch Migräne, Deutsche med. Wchnschr. **48**:1408-1409, 1922.
6. Wegner, W.: Augenspiegelbefunde bei Migräne, Klin. Monatsbl. Augenh. **76**:194-202, 1926.
7. Vallery-Radot, P.: Une figure originale, le Docteur Véron, Progr. méd., Paris, supp., pp. 41-46, 1937.

REPORT OF A CASE

History.—A white woman, aged 49, separated from her husband, was admitted to the hospital complaining of severe headache and loss of vision of the right eye. She had had headaches since the age of 14. The pain was in the entire cranium, was not preceded by a specific aura and was accompanied with "fireworks" visual phenomena and central visual scotomas. Severe nausea with vomiting developed, and the patient would drop off into an exhausted slumber,

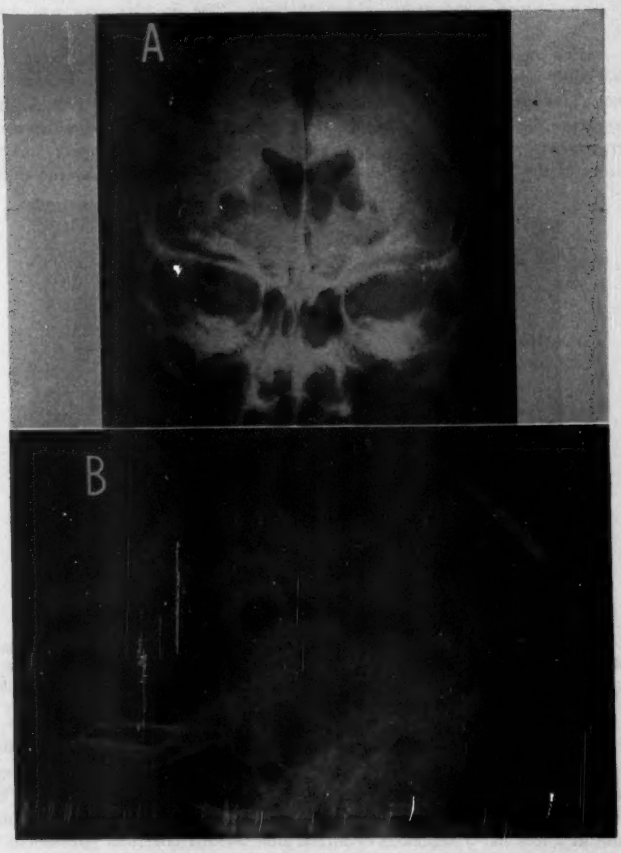

Fig. 1.—In an effort to rule out the presence of a space-taking lesion as the cause of the right hemicrania with occlusion of right central retinal vein, combined pneumoencephalographic and ventriculographic studies were performed. The anteroposterior (*A*) and lateral (*B*) views conclusively rule out the existence of such a mass.

to awaken tired but relieved. The attacks lasted from four to 24 hours and recurred every three to four months.

General Physical Examination.—The patient was well developed and well nourished and appeared extremely apprehensive. Examination of the head, skin, ears, nose, throat, neck and chest was noncontributory. The abdomen presented three well healed scars. There was marked

limitation of motion of the left elbow, due to a previous injury. Neurological examination revealed no loss of sensation or motor ability, nor were pathological reflexes present. Blood pressure readings varied but averaged 135 systolic and 90 diastolic.

Examination of the Eyes.—Visual acuity of the right eye was limited to recognition of hand motion at 2 feet (60 cm.); that of the left eye was 20/20. Ophthalmoscopic examination of the left eye revealed nothing abnormal, but the findings were strikingly pathological in the right eye. The disk margin was completely blurred. The veins were dilated and tortuous, with numerous flame-shaped hemorrhages alongside them. The macular area was not definitely made out.

After routine analgesia and use of such drugs as ergotamine tartrate, oxygen and snake venom had failed to relieve the symptoms or improve the visual acuity over a two day period, the patient was given a cervical sympathetic ganglion block with 1 per cent procaine hydrochloride and two courses of intravenous procaine therapy. The amount of procaine hydrochloride given intravenously was 500 mg. in 500 cc. of 5 per cent dextrose in water, injected slowly. Visual acuity of the right eye then improved (within 12 hours) to 20/20, and then to 20/50.

Fig. 2.—On the second attempt, successful right carotid angiography was accomplished in an attempt to rule out the existence of an aneurysm of the internal carotid artery or one of its branches. The radiology department reported that the lateral view shown in this figure precludes such a possibility.

Perimetric examination with a 3/1000 target revealed enlargement of the blindspot to twice its normal size. The fundus did not change before the patient's discharge from the hospital.

Forty-five days later the patient was again admitted to the hospital with identical complaints and a similar history. Visual acuity of the right eye was again limited to the recognition of hand motions at 2 feet, but it improved to 20/200 after another course of intravenous injections of procaine. Ophthalmoscopic examination of the left eye continued to show a normal condition, but revealed the disk margin of the right eye to be indistinct, with hemorrhages and exudates adjacent to and superimposed on the disk; the macular area contained hard, radially arranged exudates in "star" formation. There were markedly dilated, sausage-shaped veins, with an increased arteriovenous ratio. Numerous punctate and flame-shaped hemorrhages were observed in the periphery. The visual acuity soon returned to counting fingers at 2 feet.

The departments of neurology and neurological surgery were consulted, since the commonest cause of hemicrania with occlusions of the central retinal vein is thought to be an expanding intercranial tumor or an arterial aneurysm. In the light of this fact, combined pneumoencephalographic and ventriculographic studies (fig. 1 *A* and *B*) were done. A space-filling

lesion was thus ruled out. Right carotid angiography revealed no filling of the internal carotid artery, but a second attempt (fig. 2) showed good reflux filling of the artery.

Twelve weeks after the onset of the second attack the visual acuity had not improved in the right eye from ability to count fingers at 2 feet. The right fundus (fig. 3) now showed absorption of the flame-shaped hemorrhages, continuation of the blurring of the disk margin and increase in the perimacular exudation. The periphery of the fundus showed stippled pigment degeneration and was pale.

The final diagnosis was occlusion of the central retinal vein of the right eye as a result of atypical migraine.

COMMENT

The case reported describes a direct complication of an attack or of a series of attacks of migraine. The question now arises as to what can be learned from this case with respect to the association of the intracranial and the ocular circulation, and the relation of the ocular vessels to vasospastic disease.

Fig. 3 (courtesy of the Estelle Doheny Eye Foundation).—Photograph of fundus taken approximately three months after onset of the second attack. The disk margin is completely blurred, a well developed macular "star" persists, the veins are dilated, and the periphery of the fundus shows the residua of large hemorrhages.

Many authorities believe that the attack of migraine may be roughly broken into two parts. The first, or vasoconstriction, is the preheadache period. In this phase are found the visual phenomena generally associated with migraine. Scotomas are thought to result from spasms of the posterior cerebral artery, with resultant ischemia of portions of the occipital cortex.[8] The occurrence of retinal arterial spasm in the early phase of attacks of migraine has occasionally been described. When retinal arterial spasm is severe, occlusion of the affected vessels may occur, leading to a permanent defect in the field of vision. This occasional development of retinal artery occlusion offers direct and visible evidence of vaso-

8. Engel, G. L.; Ferris, E. B., Jr., and Romano, J.: Focal Electroencephalographic Changes During Scotomas of Migraine, Am. J. M. Sc. **209**:650-657, 1945.

spasm in the early stages of a migraine attack, for it seems altogether probable that such occlusion leads to thrombosis and that this thrombosis is secondary to spasm of the affected vessel.[8] This vascular spasm is regarded by most observers as the cause of the transient focal symptoms so frequently associated with migraine, viz., scotomas, paresthesia, paresis of the extremities and aphasia.[9]

The second, or vasodilatory, phase accounts for the headache, nausea and vomiting on the same basis as histamine toxicity, i. e., a direct function of dilatation of the cerebral vessels. Optic disks have been examined repeatedly at the time of both scotoma and headache, without, as a rule, any changes being seen; but veins have been engorged during the headache and arteries constricted during the time of the scotoma, their caliber increasing with the return of vision.[10]

In order to explain why one particular attack of migraine should precipitate these irreversible vascular changes, and why these changes occur at all, some authors have postulated that numerous, repeated vascular explosions, such as that undergone in the biphased migraine attack, are in themselves sufficient to cause intimal damage and produce a rather localized atherosclerotic process. It is evident that in the presence of cerebral atherosclerosis, however slight, crises of hemicrania are much more likely to be the cause of vascular accidents, such as hemorrhage and thrombosis, than would be the case in normal vessels.[9]

One is led to conclude that the neural mechanisms regulating the caliber of the blood vessels in the intracranial vault and those of the eye are either identical or intimately related. What happens to one set of vessels on a neuromechanical basis apparently happens also to the other. It is of interest to draw a parallel between the results which follow the curtailment of the supply of blood to the retina as a result of sclerosis of its arteries, with subsequent thrombosis of its veins, and the corresponding results of a similar process in the brain.[11] The evidence available from both clinical and experimental observation suggests that the symptoms of migraine result from the alteration of the caliber of the blood vessels in the head and that both the intracranial and the extracranial vessels take part in this process.[8]

SUMMARY

The reported cases of permanent vascular damage to the eye as a complication of migraine are tabulated, and a case of occlusion of the central retinal vein associated with migraine is presented. Possible underlying pathologic processes and the relation of the intercranial to the ocular circulation are discussed.

9. Hunt, J. R.: A Contribution to the Paralytic and Other Persistent Sequelae of Migraine, Am. J. M. Sc. **150**:313-330, 1915.

10. Wilson, S. A. K.: Neurology, Baltimore, Williams & Wilkins Company, 1940, p. 1587.

11. Berens, C.: The Eye and Its Diseases, Philadelphia, W. B. Saunders Company, 1949, p. 663.

Registry of Interesting Cases

It is the purpose of this section to record cases on the basis of interest only. No complete review of the literature is attempted and no claim for priority is implied except when specifically stated. Publication of case reports is subject to the concurrence of the Editorial Board on the interesting aspects of the case. It is requested that the reports submitted be as brief as is consistent with inclusion of the pertinent facts, bear a title that is as specific as possible, be prefaced by a paragraph that states why the author feels the case is of interest and be accompanied with photographs whenever possible.

OPTIC ATROPHY, UVEITIS AND INTRACRANIAL DISEASE

The patient in this case presented the unusual combination of optic atrophy in one eye, uveitis with a cecocentral scotoma in the other eye, lymphocytosis in the spinal fluid and neurologic evidence of an intracranial lesion. Of the various diagnostic possibilities (Devic's disease, disseminated sclerosis, Vogt-Koyanagi syndrome), basal arachnoiditis seemed to explain best the entire entity.

J. S., a man aged 21, had had optic atrophy of the right eye eight years previously, for no apparent reason. Eight months prior to admission, the patient had experienced symptoms in the left eye for the first time. These consisted of black spots.

His corrected visual acuity at this time was found to be 3/150 in the right eye and 6/9 — in the left eye. On examination, the right eye showed primary optic atrophy but was otherwise normal. The left eye showed a diffuse type of uveitis. The cornea was studded with keratic precipitates; the aqueous and vitreous showed numerous floating opacities, and the iris markings were obscured. The peripheral visual fields in both eyes were normal to a 1/330 test object. The central field of the left eye was normal to a 1/1000 test object, but the central field in the right eye showed a cecocentral scotoma with the 2/1000 test object.

The skin test with brucellergen gave a negative reaction. The first test with purified protein derivative of tuberculin U. S. P. gave a negative reaction, and the second test, a mildly positive reaction. The reaction for lymphogranuloma was negative. The results of laboratory studies, including a complete blood count, determinations of the fasting blood sugar and serologic tests of the blood and spinal fluid, were within normal limits. The electroencephalogram was normal. A dental roentgenogram showed some caries in the upper incisors, with no evidence of periapical disease. Roentgenograms of the skull, paranasal sinuses and optic foramens revealed no abnormality. The lung fields were normal.

A neurologic consultant reported bilateral hyperactive deep reflexes; a bilateral Hoffmann sign, more marked on the left; a bilateral Babinski sign, and left ankle clonus. The spinal fluid showed lymphocytosis, with a count of 40 per cubic millimeter, and a protein content of 40 mg. per 100 cc. but was otherwise normal. Because of the cells in the spinal fluid, the patient was transferred to the neurologic service, where he was further evaluated.

A course of cortisone was given. He received a total dose of 800 mg. and at the same time was given aureomycin and streptomycin systemically. There was very little change in the uveitis and no change in the optic atrophy.

During his stay in the hospital, however, a cecocentral scotoma developed in the left eye, similar to that in the right. Repeated spinal fluid examinations showed lymphocytosis, the count varying from 25 to 30 per cubic millimeter.

After his return home acute appendicitis developed, and after operation the left eye started to clear up. A letter from the family states that the vision in the left eye has improved considerably and there are now no symptoms of inflammatory disease in the eyes.

FRANCIS H. ADLER, M.D.
313 South Seventeenth Street
Philadelphia

Annual Reviews

OPTICS AND VISUAL PHYSIOLOGY

Review of Literature for 1949 and 1950

KENNETH N. OGLE, Ph.D.
ROCHESTER, MINN.

ABERRATIONS OF THE EYE

RESEARCH on the problem of the spherical aberration of the eye has been given impetus during the last few years in the United States and other countries because this aberration is a possible cause of night myopia. It was frequently reported during the last war that men in the armed forces who used binoculars, telescopes and periscopes at night tended to focus the eyepieces as though the eyes had become myopic when adapted to night conditions. The amount of this so-called night myopia on the average was found to be between —1 and —2 D., but this varied greatly among individual subjects, and in some cases was as much as —3 D. Chromatic aberration of the eye, together with the Purkinje shift in retinal sensitivity in scotopic vision, could account for at most only 0.5 D. of this myopia.[1] Koomen, Tousey and Scolnik [2] have shown that this myopia probably could be attributed to the spherical aberration of the eye. The effect of spherical aberration would be greater at night, when the pupil is dilated, than in the daytime. Evidence indicates that the pupillary reflex is confined entirely to the photopic range of illumination and is therefore essentially initiated by the cones of the retina.[3] Because of the apparent myopia in night vision, Katz,[4] who also studied the problem, suggested that a —1 D. error be built into the eyepieces of instruments with nonadjustable eyepieces.

Ivanoff [5] studied the range of accommodation of the human eye when the center of the pupil was used and when only an area 1.5 mm. away from that center was used and found a difference of 1.2 D. (6.4 D. on the axis, 5.2 D. off axis). There was a difference on the nasal and on the temporal side. This difference was also explained by spherical aberration. The latest experimental work [6] justifies the

From the Section on Biophysics and Biophysical Research, Mayo Foundation and Mayo Clinic.

1. (*a*) Wald, G., and Griffin, D. R.: The Change in Refractive Power of the Human Eye in Dim and Bright Light, J. Optic. Soc. America **37**:321-336 (May) 1947. (*b*) Ivanoff, A.: Chromatic Aberration of the Eye, Docum. ophth. **3**:322-323, 1949.

2. Koomen, M.; Tousey, R., and Scolnik, R.: The Spherical Aberration of the Eye, J. Optic. Soc. America **39**:370-376 (May) 1949.

3. de Launay, J.: A Note on the Photo-Pupil Reflex, J. Optic. Soc. America **39**:364-367 (May) 1949.

4. Katz, J.: Untersuchungen über eine feste Okulareinstellung an Ferngläsern und Periskopen zum Gebrauch bei Tage, in der Dämmerung und bei Nacht, Klin. Monatsbl. Augenh. **114**:71-82, 1949.

5. Ivanoff, A.: Au sujet des variations de l'amplitude d'accommodation de l'oeil suivant la région utilsée de la pupille, Compt. rend. Acad. sc. **230**:1896-1897 (May 22) 1950.

6. Koomen, R.; Scolnik, R., and Tousey, R.: A Study of Night Myopia, J. Optic. Soc. America, to be published.

conclusion that night myopia is due to the spherical aberration of the eye, without there being any accommodative act of the eye. Ivanoff [7] did find evidence, however, that the positive spherical aberration of the eye was reduced when the eye accommodated. This effect must be due to an increase in the index of refraction of the lens as a whole, along the axis from 1.420 to 1.425, while at the peripheral parts there should be hardly any change.

Fry [8] considered theoretically the combined effects of spherical aberration and diffraction on the retinal image and concluded that no peaks of light intensity in the retinal image existed that would correspond to the intersection of the caustic surface and the retina; hence the caustic surface is of little value in predicting the light intensity on the retina.

The old problem of why chromatic fringes are not seen by the eye by virtue of the chromatic aberration of the eye is discussed by Hartridge,[9] who assumes that the physical chromatic aberration of the eye is corrected by special physiologic properties of the receptor apparatus of the retina.

REFRACTION TESTS

The papers dealing with problems of the testing of refractive errors as usual point toward more accurate results and speedier examinations.

On a theoretical basis that the first impulse to an accommodative change originates when the size of the light circle of confusion on the retina exceeds the size of the central diffraction disk, Katz [10] concluded that a visual test chart need not be nearer than 5 m. for a pupil of 2.8 mm. and 10 m. if the pupillary diameter is 4 mm. or larger. At greater distances no accommodation will occur, and therefore testing at greater distances is of no special value unless zero convergence is desirable. The intensity of illumination of the visual test chart and of the examining room is important, therefore. An illumination ratio of 10:1 gives an increase in acuity of one line of the Snellen chart.[11]

Tests are constantly being devised with which it is hoped to improve the accuracy in refraction measurements or to assure that the accommodation is relaxed or of a specified state. Littmann [12] has designed a precision retinoscope based on the Foucault knife test, a test used for accurate determination of the focal properties of lenses. Essentially, Littmann's retinoscope differs little from the conventional retinoscope. The principal feature of his method, however, is that the skiascopic measurements are made along the visual (foveal) axis of the eye, and the subject's fixation is controlled by a special target. The subject's head is held in a head rest.

7. Ivanoff, A.: Essai d'interprétation de l'aberration sphérique de l'oeil et ses variations avec l'état d'accommodation, Compt. rend Acad. sc. **228**:126-128 (Jan.) 1949.

8. Fry, G. A.: Combined Effects of Spherical Aberration and Diffraction on the Retinal Image, Am. J. Optometry **27**:126-136 (March) 1950.

9. Hartridge, H.: The Chromatic Aberration of the Human Eye and Its Physiological Correction, Experientia **6**:1-10, 1950.

10. Katz, J.: Bemerkungen zur Frage der Akkommodation und Konvergenz, Klin. Monatsbl. Augenh. **115**:134-136, 1949.

11. Gilbert, M., and Hopkinson, R. G.: Illumination of the Snellen Chart, Brit. J. Ophth. **33**:305-310 (May) 1949.

12. Littmann, H.: Foveale Präzisionsskiaskopie, von Graefes Arch. Ophth. **149**:520-539, 1949.

The subject fixates a target seen by reflection from an inclined plate of glass before the eye being examined. The retinoscopic examination is made through the glass. Littmann claimed a precision of ±0.07 D. without the use of mydriatics and of ±0.03 D. when 1 per cent solution of homatropine is used. Comparative results with a subjective fogging method were excellent, although the scatter of the points representing the measurements of the subjective method was fifteen times that for the skiascopic data. The apparent distance of the fixation target could be varied by optical means [13] so that the stimulus for accommodation could be regulated by the vergence of light corresponding to positions of the target beyond the far point. Thus, the accommodation of the hypermetropic eye could be relaxed. The best relaxation was obtained when the fixation point was +2 D. more hypermetropic than the real value of the eye.

Also, using a test target the optical distance of which could be varied in 0.5 D. steps (with auxiliary lenses for subjects with high refractive error), Fleury [14] has designed what he calls a rapid subjective test. The essential problem is the selection of a suitable target. One consisting of lines of bright point light sources passing through the center of the chart (and this rotatable) appears best.

On the assumption that a monocular test of refraction while the two eyes are used simultaneously in binocular vision is desirable, Morgan [15] has reexamined the Turville Infinity Binocular Balance Test.[16] In this test the subject sees binocularly the peripheral parts of a suitable target, the central parts being obscured by a suitable septum and screen. With the American Optical Project-O-Chart, Snellen type letters are projected at the center of the target, and the screen and septum are arranged so that only one eye at a time can see the letters. With this arrangement, more than 200 subjects underwent refraction, and, for comparison, these also underwent refraction under the usual test conditions. In less than 10 per cent of the subjects were significant differences between the two methods found.

Clinical experience seems to indicate that the single pair of crossed lines of the Lancaster-Regan astigmatic chart is the most accurate for the determination of the power of the astigmatic correction. Less simple, perhaps, is the exact determination of the axis of astigmatism by the same chart. Crisp and Stine [17] emphasize the accuracy and ease of using the Jackson cross cylinder with this chart for the determination of axis. Lebensohn [18] has suggested the addition of two short lines 60 degrees apart (after Verhoeff) as an "arrow" to one of the cross lines of the same chart. The axis of the cylinder correction is accurately given by the position at which this "arrow" points when the two "wings" which make up the arrow appear of equal

13. Littmann, H.: Über die Akkommodationsentspannung mit optischen Methoden, Klin. Monatsbl. Augenh. **115**:136-142, 1949.

14. Fleury, P.: Rapid Subjective Examination in Optometry, Rev. optique **29**:384-394 (July) 1950.

15. Morgan, M. W., Jr.: The Turville Infinity Binocular Balance Test, Am. J. Optometry **26**:231-239 (June) 1949.

16. Turville, A. E., cited by Morgan.[15]

17. Crisp, W. H., and Stine, G. H.: A Further, Very Delicate Test for Astigmatic Axis, Using the Cross Cylinder with an Astigmatic Dial and Without Use of Letter Charts, Am. J. Ophth. **32**:1065-1068 (Aug.) 1949.

18. Lebensohn, J. E.: A Simplified Astigmometer, Am. J. Ophth. **32**:1128-1130 (Aug.) 1949.

contrast. Stine [19] objects, however, that this addition, while ingenious, adds to the subject's confusion and is unnecessary if the cross cylinder is used according to the Crisp-Stine routine.

In recent years there has been interest in the stigmatoscopy method of refraction, which permits binocular vision during the test (a method based on that of Badal), especially as developed by Lancaster and associates. A complete description of that method is given by Bannon and associates.[20]

The Helmholtz cobalt glass test has also been reexamined and improved by Rössler.[21] Since cobalt glass transmits only the deep red and the deep blue ends of the spectrum, in the human eye this amounts to a difference of refraction of nearly 2 D. (according to Rössler, although this appears too great).[18] When a bright point of light is fixated, if the uncorrected eye is myopic a red disk surrounded by a blue marginal ring will be seen; if the uncorrected eye is hypermetropic a blue disk surrounded by a red marginal ring will be seen. If the eye is emmetropic or accurately corrected the two blur disks on the retinas should be superimposed. Various attempts have been made to utilize this principle as a test for refraction. Irregular scattering of light by the media of the eye often interferes with the test. Here Rössler has modified the test, and in his opinion it is now practical. The chief advantage would be in the determination of the spherical correction.

AMETROPIA

The frequency distribution of the general population according to refractive errors is frequently referred to as the refraction curve. This curve, according to many investigators (for example, Stenström [22]), departs from a normal distribution curve in that there are an excess of emmetropes at the center of the curve and an excess of hypermetropes and myopes (especially) at the extreme ends of the curve. Many workers have attempted to account for this distribution. This problem is especially intriguing because repeatedly experimenters have shown that the frequency distributions of corneal curvatures, radii of curvature of the lens, depth of anterior chamber and axial lengths, each show a normal distribution.

Betsch,[23] who with collaborators had previously gathered data on the total refractive error of more than 12,000 eyes, attempted to explain the "excess" by assuming (after Berg) that it rests on different groupings of the eyes, combined in such a way that they vary among themselves solely in the corresponding behavior of the constituent parts. Betsch constructed two normal refraction curves on the assumption that in the first group a fixed correlation exists between corneal curva-

19. Stine, G. H.: The Crisp-Stine Test for Astigmatism and the Lebensohn Astigmometer, Am. J. Ophth. **33**:1587-1590 (Oct.) 1950.

20. Bannon, R. E.; Cooley, F. H.; Fisher, H. M., and Textor, R. T.: The Stigmatoscopy Method of Determining the Binocular Refractive Status, Am. J. Optometry **27**:371-384 (Aug.) 1950.

21. Rössler, F.: Von Helmholtz'schen Kobaltversuch, Ophthalmologica **118**:149-160 (Sept.) 1949.

22. Stenström, S.: Untersuchungen über die Variation und Kovariation der optischen Elemente des menschlichen Auges, Acta ophth., supp. 26, 1-103, 1946; translated by D. Woolf, Am. J. Optometry **25**:218-503 (May-Oct.) 1948.

23. Betsch, A.: Zum Problem der Refraktionskurve, Klin. Monatsbl. Augenh. **115**:205-213, 1949.

ture and axial length, and in the second only that the axial length varies normally within certain limits. Putting the two groups together under the condition that there were twice as many of the second group as of the first group, he obtained a total refraction curve that exhibited the characteristics of the excess of the empirical refractive curve. By a somewhat similar procedure, Hirsch [24] sought to show that the myopic side of the refraction curve could be the combination of three types of myopia. Mihályhegyi [25] found no connection between the curvature of the frontal part of the eye and the degree of myopia.

Weymouth and Hirsch,[26] using the published data of Collins (1890), Weiss (1897) and Deller, O'Conner and Sorsby (1947) on the measured diameters of the eyes (the last by roentgenologic methods), analyzed the data according to age. They found that (1) a relative higher variability exists for the diameters of eyes than exists for other skeletal dimensions, (2) the vertical and transverse diameters grow approximately at the same rate and (3) the axial length increases after birth less rapidly than, and later at the same rate as, does the vertical diameter. The rate of growth and the age at which the growth period ends vary with the individual person. Those whose eyes stop growth relatively early tend to show short axial lengths, and therefore tend toward hypermetropia. Persons with large eyes that resulted from a rapid and continued growth tend to have long axial lengths and thus are myopic.

From the refraction data of more than 35,000 eyes, together with similar data of Brown, Slataper [27] ascertained the average refractive error for persons in all age groups from birth to 87 years. The spherical equivalent in each case was taken as the refractive error. This method of stating the refractive error is not without criticism, however. A graphic representation of the data shows a curve with two maxima (at 7 years and 65 years) and a minimum at about 31 years. At birth the norm is +2.32 D. of hypermetropia, which increases 1.62 D. until about the age of 7 years, after which this hypermetropia decreases to a minimum of +0.61 D., at the age of 30 years. From this age the hypermetropia then increases slowly at first, then rises to a maximum of about +2.00 D. at the age of 64 years. Senile myopia then develops rapidly beyond 68 years. In Slataper's opinion, such data are valuable as an aid to the prognosis of the possible future course of refractive errors beginning at any given age, and especially to the possibility of the development of cataract. In a group of 228 boys of the average age of 14 years, however, reexamined by the Massachusetts Vision Test at the end of three years, Sloane and Gallagher [28] found that in about 75 per cent no changes in refraction had occurred. In a study

24. Hirsch, M. J.: An Analysis of Inhomogeneity of Myopia in Adults, Am. J. Optometry **27**:562-571 (Nov.) 1950.

25. Mihályhegyi, G.: Neue Beiträge zur Krümmung der vorderen Augapfelhälfte, Ophthalmologica **119**:344-363 (June) 1950.

26. Weymouth, F. W., and Hirsch, M. J.: Relative Growth of the Eye, Am. J. Optometry **27**:317-328 (July) 1950.

27. Slataper, F. J.: Age Norms of Refraction and Vision, Arch. Ophth. **43**:466-481 (March) 1950.

28. Sloane, A. E., and Gallagher, J. R.: Changes in Vision During Adolescence, Am. J. Ophth. **33**:1538-1542 (Oct.) 1950.

of the hereditary factor in myopia, Wold [29] distinguishes two types of myopia: hereditary and acquired. Commonest is the recessively hereditary form; the sex-linked recessive form occurs less often. Thirty-five per cent of the myopic children studied had parents without myopia, but 49 per cent had one or both parents with myopia.

The relation of corneal astigmatism, lenticular astigmatism and total astigmatism of the eye has again been studied by Hruby,[30] who examined more than 800 eyes, using the ophthalmometer and the retinoscope. He calculated the lenticular astigmatism from the rule: L.A. = 3/2 (total — corneal). He concluded that the relationship between the astigmatic components of the eye shows no simple regularity. There appears a fundamental tendency for the eye to approach a spherical state. The lenticular astigmatism, which is found frequently, tends to reduce the astigmatism of the cornea. Exceptions are found in cases of high astigmatism with the rule. The lenticular astigmatism is usually small, never exceeding 2 D. Generally the axes of the corneal astigmatism and of the lenticular astigmatism are different, especially in cases of corneal astigmatism at oblique axes. Hruby concluded that the use of the ophthalmometer alone may lead to gross error in determining the true ocular astigmatic error.

However, Bonneval [31] in his study of the literature found general agreement with the data that in emmetropia or spherical refractive error there is almost always a corneal astigmatism of about 0.75 D. (greatest curvature in the vertical) and also that most crystalline lenses exhibit an astigmatism of about 0.75 D. with maximal power in the horizontal meridian. Bonneval advances the hypothesis that this lenticular astigmatism is the primary factor and a characteristic constant of the eye, that of the cornea being merely an adaptation to render the eye emmetropic. On that basis, one should be able to find the total astigmatism of the eye from the ophthalmometric measurement alone. Bonneval tested his hypothesis in cases of astigmatism at oblique axes, combining the two cylinder lens powers indicated by the ophthalmometer with the + 0.75 D. at axis 0, as one would combine crossed cylinders. The result is correlated with the measured total astigmatism. In a study of 234 eyes with astigmatism at oblique axes, he found that 147 confirmed his hypothesis, 57 were neutral and 30 gave opposing evidence.

Statistical studies of the precision and correlation of refractive methods with adequate controls of test and retest have been few. Nordlöw [32] reports such a study in which the retinoscopic method with eyes under cycloplegia and Donders' subjective method were used. The standard errors of the two methods are similar when measured to the same exactness (±0.25 D.). The comparison of the skiascopic finding with that in Donders' method shows an agreement in 77 per cent of the cases within the real limits of 0.66 D. In 23 per cent the skiascope yielded a higher hypermetropia than did Donders' method. The sources of error in the examination are carefully considered.

29. Wold, K. C.: Hereditary Myopia, Arch. Ophth. **42**:225-237 (Sept.) 1949.

30. Hruby, K.: Die Beziehungen zwischen Hornhautastigmatismus, Linsenastigmatismus und Gesamtastigmatismus des Auges, von Graefes Arch. Ophth. **150**:91-119, 1950.

31. Bonneval, G.: Ophthalmométrie et astigmatisme, Arch. opht. **10**:629-635, 1950.

32. Nordlöw, W.: To the Accuracy of the Objective and Subjective Method of Determining the Refraction of the Eye, Acta ophth. **27**:349-378, 1949.

The literature dealing with the contact lens is considerable. No attempt will be made here to summarize this. Special attention is being given to the corneal lens (especially that of the Tuohy type), which, it is claimed, is superior to the conventional lens with respect to comfort of the patient, fogging of lens, ease of insertion and removal, technic of fitting and general appearance on the eye.

In order to obtain a high magnification of the retinal image in cases of subnormal vision, Sautter [33] suggests (as had previously been done) that a contact lens of about a —20 D. power be used and that this error be corrected by a positive ophthalmic lens 15 to 20 mm. from the cornea. The result is a magnification of two to three times. This device gives a greater visual field, allows freer eye movements and increases the intrinsic brightness of the image as compared with the usual telescopic lens.

ANISEIKONIA

Articles in this field, especially in journals published outside the United States (for example, Albrich [34] and Carreras Duran [35]), still show a remarkable unfamiliarity with the literature on the subject. It is hoped that the recent book by Ogle,[36] the last quarter of which is devoted to the theoretical and experimental bases of aniseikonia, will help to make for a better understanding of the subject. Albrich constructed an eikonometer using a haploscope, the targets of which consisted of two separated point light sources. A direct comparison of the relative apparent separation of those as seen by the two eyes was made. No fusion details were included.

Data are presented [37] which show a high correlation between aniseikonic measurements made for distant vision and those for near vision. On the basis of this correlation the design of the eikonometer can be modified, so that the test is made only for distant vision (when sensitivity is higher than for near vision and the problem of the "add" for near vision is avoided); the time of examination is then decreased.

The fact that cylinders used to correct the astigmatism of the eye alter the magnification of the retinal image is discussed by Hallett.[38] More generally, the magnification is considered by Ogle.[36] Similarly, Bürki [39] reviews the facts that magnification of the retinal image, when contact lenses are used to correct the ametropia, depends on the cause of the ametropia. In the case of axial myopia, the image is increased in size, and in high degrees of myopia this may reach 50 per cent. In axial hyper-

33. Sautter, H.: Über die Modifikation des Fernrohrbrillensystems durch die Verwendung von Haftschalen, von Graefes Arch. Ophth. **149**:142-155, 1949.

34. Albrich, K.: Die Aniseikonie und der Kliniker, Klin. Monatsbl. Augenh. **114**:420-428, 1949.

35. Carreras Duran, B.: En torno a la aniseiconia, Arch. Soc. oftal. hispano-am. **9**:934-941 (Sept.) 1949.

36. Ogle, K. N.: Researches in Binocular Vision, Philadelphia, W. B. Saunders Company, 1950.

37. Ogle, K. N., and Triller, W.: Aniseikonia for Distant and Near Vision, Am. J. Ophth. **32**:1719-1724 (Dec.) 1949.

38. Hallett, J. W.: The Optics of Cylinder Magnification, Am. J. Ophth. **33**:1090-1095 (July) 1950.

39. Bürki, E.: Die optische Wirkungsweise des Haftglases und ihre Bedeutung für die Ophthalmologie, Ophthalmologica **118**:215-233, 1949.

metropia the image is decreased in size. However, in refractive ametropia (curvature or indicial) the size of the image is only slightly changed. Thus, in cases of anisometropia of refractive origin contact lenses may be useful.

VISUAL ACUITY

Comparison of five different letter test charts by Arndt [40] shows great lack of uniformity, and sources of errors. Letters were better recognized than numbers. A new chart is proposed which, Arndt claims, fulfills the requirements of the Snellen principle of the 1 minute angle, and yet the letters are more uniform in their difficulty of being recognized than in the other charts which he compared. Letters L, Z, I, U and A are omitted as too easy to discriminate. The chart is confined to the letters B, D, G, O, C, H, K, M and N.

Again, apparatus has been designed to measure the visual acuity of subjects objectively by the use of optokinetic nystagmus. Rochels [41] uses a moving strip of three checkerboard patterns of different-sized squares, one above the other. This observation target can be placed at various distances. The nystagmus can be observed as long as the patient is able to resolve the checkerboard pattern. Critical distances are determined, and the visual angle of pattern corresponding to the usual acuity scale is calculated.

That visual acuity may be lower in the oblique than in the vertical or horizontal meridians is reported by Higgins and Stultz.[42] With test targets consisting of a parallel line grid the acuity in the oblique meridians may be 20 per cent poorer than in the vertical or horizontal meridians. It was suggested that this difference might be due to differences in the directions of the physiologic nystagmus of the eyes,[43] but later experiments [44] have shown that the effect persists even with flash exposures of one millisecond. This precludes the possibility that ocular movements explain the orientation effect. The very existence of the phenomenon has been denied by some experimenters.

In studying visual acuity thresholds, Jones and Higgins [45] present a hypothesis that the physiologic nystagmus, especially those eye movements corresponding to 25 cycles per second and an amplitude of 214 minutes of arc, subjects the cones to a temporal gradient of illumination and that this can lead to higher visual acuity. Studies by Martin and associates [46] on the thresholds of visual acuity with brief stimuli show (among other things) no evidence that these eye movements improve

40. Arndt, G.: Über Unterschiede zwischen verschiedenen Sehproben, Klin. Monatsbl. Augenh. **115**:157-161, 1949.

41. Rochels, K. H.: Über ein Gerät zur objektiven Sehschärfenbestimmung, Klin. Monatsbl. Augenh. **116**:31-34, 1950.

42. Higgins, G. C., and Stultz, K.: Visual Acuity as Measured with Various Orientations of Parallel-Line Test Object, J. Optic. Soc. America **38**:756-758 (Sept.) 1948.

43. Brown, W. R. J.: Eye Movements and the Variation of Visual Acuity with Test Object Orientation, abstracted, J. Optic. Soc. America **39**:1057 (Dec.) 1949.

44. Higgins, G. C., and Stultz, K.: Variation of Visual Acuity with Various Test-Object Orientations and Viewing Conditions, J. Optic. Soc. America **40**:135-137 (March) 1950.

45. Jones, L. A., and Higgins, G. C.: Photographic Granularity and Graininess: IV. Visual Acuity Thresholds; Dynamic Versus Static Assumptions, J. Optic. Soc. America **38**:398-405 (April) 1948.

46. Martin, L. C.; Day, D. J., and Kaniowski, W.: Visual Acuity with Brief Stimuli, Brit. J. Ophth. **34**:89-104 (Feb.) 1950.

visual acuity. In fact, very recently Ratliff [47] has found in recorded eye movement, with light reflected from a contact lens, that the involuntary "drifts" of the eye during presentation of visual acuity test targets definitely depress the visual acuity. The very rapid tremors [48] of the physiologic nystagmus apparently have no effect.

The problem of why measurements of visual acuity made binocularly are significantly higher than those made monocularly has been studied by Horowitz [49] statistically with careful controls. His results seem to indicate that the pupillary change in both eyes caused by the reduced illumination of the occluded eye in the monocular tests tends to reduce the acuity. However, this is not the only factor, for when the illumination of the occluded eye is increased, the difference between the results of the binocular and of the monocular tests is reduced but is not entirely eliminated. Hence other interactions, such as rivalry or fusion effects, presumably are present. Not to be omitted also are the effects of the images of the boundary and of the contours of the test targets in which those seen binocularly would aid and fill out the deficiencies of each eye. The chance factors suggested by Pirenne and by Bárány would play a minor role in explaining the difference.

Visual acuity of details on objects in motion is an important problem in physiologic optics and is one on which little work has been done. By rotating a prism before one eye, Ludvigh [50] investigated the visual acuity of targets appearing to move in a circle (in the frontoparallel plane), under various conditions of speed, illumination and extrafoveal vision. His results show a precipitous drop in visual acuity as the angular rotation is increased, the decrease being nearly linear with respect to angular rotation. At an angular velocity of 61.5 degrees per second the acuity dropped to 0.08. The decrease in acuity is attributed to imperfect ocular pursuit movements. Recently Kephart and Besnard [51] studied the ability of the eye to discriminate details on spheres rolling down an incline. Differences were found depending on whether the spheres were observed from the side or with an end view. The angular speed would be an important datum needed if one were to differentiate the essential differences in this case.

To obtain information about the minimal number of retinal elements (cones) involved in the resolving power discrimination, Weber [52] determined (1) the minimal amount that the middle of three point light sources had to be displaced to be perceived as being just out of line with the outer two, and (2) the minimal displacement so that the inner edge of the blur circle of the middle point was tangent to the line from the edges of the blur circles of the two outer points. He found that the first was of the order of 25 seconds of arc and that this value was independent of the contrast (ratio of intensity of point light sources to background illumination

47. Ratliff, F.: The Role of Physiological Nystagmus in Visual Acuity, abstracted, Am. Psychologist **5**:260-261 (July) 1950.

48. Riggs, L. A., and Ratliff, F.: Coordination of the Eyes in Maintaining Fixation, Am. Psychologist **5**:260 (July) 1950.

49. Horowitz, M. W.: An Analysis of the Superiority of Binocular Over Monocular Visual Acuity, J. Exper. Psychol. **39**:581-596 (Oct.) 1949.

50. Ludvigh, E. J.: Visual Acuity While One Is Viewing a Moving Object, Arch. Ophth. **42**:14-22 (July) 1949.

51. Kephart, N. C., and Besnard, G. G.: Visual Differentiation of Moving Objects, J. Appl. Psychol. **34**:50-53, 1950.

52. Weber, H. H.: Über das Auflösungvermögen des Auges, Deutsche med. Wchnschr. **75**:33-36 (Jan. 6) 1950.

and color). The second varied from 75 to 120 seconds of arc, depending on the contrast. Weber associated the first measure with the size of the anatomic structures and concluded therefore that the average value found corresponds to one-half the diameter of a cone, in conformity with histologic data. The resolving power itself, which is dependent on the excitation area, is determined less by the retinal mosaic than by the imperfection of the image on the retina.

The influence of the size of artificial pupils (and of exit pupils of telescopes) on the resolving power of the eye was investigated by Coleman and collaborators,[53] using as the Foucault test object parallel black and white bars having an inherent contrast of 94 per cent. Again it is shown that the resolving power is nearly constant for pupillary sizes larger than 2 to 2.5 mm. For smaller pupillary sizes the resolving power decreases very rapidly. Perhaps a pupillary diameter of 2.5 mm. gives a slightly higher resolving power than one of 2 mm. For pupils smaller than 0.7 mm. diffraction of light is the controlling factor. The larger test object results in a slightly better resolving power than the smaller test object.

MISCELLANEOUS OPHTHALMIC OPTICS

Safonov and Graham [54] have studied mathematically the "first order" prismatic deviation of thin ophthalmic lenses having spherical and cylindrical components. A sample nomogram for the horizontal component of the insert for such lenses is shown, which depends on the interpupillary distance, the spherical and cylindrical correction and the axis of the cylinder.

Coulman and Petrie [55] have shown that a large magnifying lens using an aspheric surface or aspheric surfaces can be designed which permits binocular observation of an object and which gives also a minimum of error in image distance for the entire object for both eyes.

OCULAR FUNCTION

The pseudotorsion of the eyes about the anteroposterior axis with eyes directed in the oblique directions has again been studied. Márquez [56] repeated and essentially verified the classic after-image experiment of Rute, Helmholtz and others. In this, an after-image of a bright cross with horizontal and vertical arms is viewed against a vertical wall, and it is observed that these arms are no longer vertical or horizontal, except in the median and visual planes. At an oblique angle the two arms no longer make a right angle; each deviates in the opposite direction in a scissors movement in the direction of gaze. Márquez incorrectly stated that Helmholtz and Donders interpreted this as meaning that the eyes had made a cyclotorsional movement. Exactly the contrary is true, for both used this experiment to

53. Coleman, H. S.; Coleman, M. F.; Fridge, D. L., and Harding, S. W.: The Coefficient of Specific Resolution of the Human Eye for Foucault Test Objects Viewed Through Circular Apertures, J. Optic. Soc. America **39**:766-770 (Sept.) 1949.

54. Safonov, G., and Graham, R.: On the Prismatic Properties of Ophthalmic Lenses, J. Optic. Soc. America **39**:406-408 (May) 1949.

55. Coulman, C. E., and Petrie, G. R.: Some Notes on the Designing of Aspherical Magnifiers for Binocular Vision, J. Optic. Soc. America **39**:612-613 (July) 1949.

56. Márquez, M.: Supposed Torsion of the Eye Around the Visual Axis in Oblique Directions of Gaze, Arch. Ophth. **41**:704-717 (June) 1949.

prove that the eye had made no torsional movement, but that the phenomenon was a result of the geometry involved of vertical flat wall and the plane of the after-image in the eye.

Similarly, Moses [57] substantiated the after-image experiments by placing on the anesthetized eye two ink marks in the vertical above and below the pupil. With eye and head in the primary position, the ink marks are alined with a plumb. When the eye is turned to look in an oblique direction, Moses noted from his point of view that the ink marks appeared turned relative to the plumb (shifted to a new position). This he assumed to mean that the eye had made cyclotorsion. Actually it had not, for again this was a phenomenon of geometry relating two frames of reference. Had he put also two ink marks in the horizontal, these would have appeared to turn in the direction opposite that of the marks placed vertically.

BINOCULAR COORDINATION

Attention is called to a new book [56] in which the significant results of the research on binocular vision conducted for the most part at the Dartmouth Eye Institute are summarized and integrated into the general body of knowledge of the visual processes. Essentially the book deals with the problem of the organization of the two eyes in the sensorial and motor aspects, the measurement of that organization, the relationship of the fusional processes and stereopsis to that organization and, finally, the probable stability of that organization.

That there exists a pupillary reflex associated only with fusion was suggested by Schubert and Burian in 1936. In this, a contraction of the pupil occurred with fusion; a dilatation, when fusion was interrupted. Marg and Morgan [58] have repeated the experiments under controlled conditions using an infrared camera to photograph the pupil. Eliminating all possible changes in convergence or accommodation when fusion was disrupted or regained, they found in 15 subjects no evidence of a pupillary reaction to fusion. The conclusion was that the earlier results must have been artefacts through changes in convergence or accommodation. The Marg-Morgan [59] studies further showed that the pupillary near reflex is essentially a phenomenon of accommodation and not of convergence, except in so far as these two functions are associated.

PRISM (FUSION) VERGENCES

The desirability of having norms for the prism vergences is generally recognized. Mellick [60] examined more than 560 subjects with the variable prism stereoscope and with the synoptophore, using two targets: flat and stereoscopic. The frequency distribution curves were not presented (unfortunately), only the averages. The synoptophore gave higher values than the stereoscope, especially at near: prism

57. Moses, R. A.: Torsion of the Eye on Oblique Gaze, Arch. Ophth. **44**:136-139 (July) 1950.

58. Marg, E., and Morgan, M. W., Jr.: The Pupillary Fusion Reflex, Arch. Ophth. **43**: 871-878 (May) 1950.

59. Marg, E., and Morgan, M. W., Jr.: Further Investigation of the Pupillary Near Reflex: The Effect of Accommodation, Fusional Convergence and the Proximity Factor on Pupillary Diameter, Am. J. Optometry **27**:217-225 (May) 1950.

60. Mellick, A.: Convergence: An Investigation into the Normal Standards of Age Groups, Brit. J. Ophth. **33**:755-763, 1949.

divergence—distant, 8 to 9Δ; near, 12 to 13Δ; prism convergence—distant, 18Δ; near, 22 to 26Δ. While Mellick found little variation in the means with age, Fischer [61] reports definite decreases in the actual limits of horizontal eye excursions (adduction and abduction) with age, as measured with 254 patients aged from 4 to 80 years, using the perimeter.

Tait [62] also studied prism vergences (fusion vergences) in 500 normal subjects who were selected on the basis that each had comfortable binocular vision and whose exophoria or esophoria was less than 2Δ. A 6/30 letter was used as test object, and the vergences were measured with the standard phorometer with Risley prisms, for distant vision. The prism values for the fusion "break" and the reversion to fusion were obtained. Cumulative distribution curves are given. Inspection of these shows the following: For divergence (prisms base in), 95 per cent of the subjects held fusion at 9Δ, 50 per cent at 13Δ but only 10 per cent at 19Δ; the maximal value found was 27Δ. Similarly, 95 per cent of the subjects recovered fusion before 5Δ, 50 per cent before 6Δ but only 10 per cent before 11Δ. For convergence, 95 per cent of the subjects held fusion at 11Δ, 50 per cent at 19Δ but only 10 per cent at 28Δ, the maximum found being 42Δ. Similarly, 95 per cent of the subjects recovered fusion before 5Δ, 50 per cent before 8Δ but only 10 per cent before 15Δ. Tait interpreted the fusion vergence data to mean that the perimacular regions of the retinas are concerned with the retention of fusion once gained, while the function of the extramacular regions is to aid in the establishment or gaining of fusion. In a later paper Tait [63] discusses, among other things, the relationship of comfortable vision and these vergences and the value of orthoptics.

Eggers [64] measured the reserve accommodation in 2,000 adults whose vision was essentially normal and whose age was less than 40 years. Minus spheres were added before both eyes at near vision until blurring occurred. An approximate linear decrease from 4 D., at the age of 20 years, to 1.5 D., at the age of 40, was found, except for a period between the ages of 26 and 30, in which the reserve accommodation was unchanged at 3.25 D.

The change in the convergence (exhibited as a change in phoria, since fusion is prevented) corresponding to a change in accommodation (minus lenses) of 1 D. is known as the accommodative-convergence ratio, or gradient. This quantity has been considered of importance as a measure of the degree to which the accommodative and convergence functions are associated. Taking at random 100 case records from some 700 records of service men at the United States Naval Training Station at Newport, R. I., Emmes [65] found that the ratios, or gradients, of these men gave approximately a normal frequency curve. The median value was 3Δ convergence for 1 D. accommodation. The standard deviation was 1.6Δ, which means essentially that the ratios of about 68 per cent of the men fell within ±1.6Δ of the 3Δ median. In the 700 cases, only 11 had a zero value. Tait [63] states that in his

61. Fischer, H.: Die physiologischen Grenzen der horizontalen Augenbewegungen, von Graefes Arch. Ophth. **150**:144-156 (Feb.) 1950.

62. Tait, E. F.: Fusional Vergence, Am. J. Ophth. **32**:1223-1230 (Sept.) 1949.

63. Tait, E. F.: Stimulus-Response Mechanisms in Binocular Coördination, Am. J. Ophth. **33**:1751-1762 (Nov.) 1950.

64. Eggers, H.: Reserve Accommodation, Arch. Ophth. **41**:701-703 (June) 1949.

65. Emmes, A. B.: A Statistical Analysis of the Accommodative-Convergence Gradient, Am. J. Optometry **26**:474-482 (Nov.) 1949.

analysis of several thousand cases these ratios vary from zero to about 7△, the great majority being between 2 and 5△. In his opinion, the association between accommodation and convergence is a learned one, and on this basis the range of ratios found can be explained. From his point of view, a total absence of the accommodation-convergence reflex is not an abnormality, nor is a small excess above the usual average limit a serious fault. There are, however, opinions divergent from this regarding the origin and the signficance of marked deviations of the accommodative-convergence ratio to binocular coordination.

By means of the phenomenon called "fixation disparity," Ogle, Mussey and Prangen [66] showed that the binocular motor behavior while fusion is maintained in the prism vergence tests and in relative accommodation tests varies greatly among subjects, and that this variation probably is an indication of the relative activity of fusion power, accommodative-convergence association, the reflex to preserve clear vision, and basic heterophoria.

With their ergographic studies, Berens and Sells [67] again report their results on the fatigue of accommodation in 57 allegedly asthenopic subjects. In 60 per cent there appeared a positive decrease (decrement) in the near point of accommodation with ergographic exercise; 18 per cent showed no change, and 22 per cent showed an improvement in ability to accommodate. While the mean decrement was statistically significant, the variation among subjects was too large for individual diagnosis. The motivation of the subject in the test was the most uncontrolled variable, and some subjects could endure the test less than the usual required time. This lack of endurance was attributed to tendency to fatigue. No correlation could be found between the decrement and refractive error, accommodative ability, phorias or asthenopic symptoms. In general, however, the ergograph seemed to increase the original phorias following the exercise. Interestingly, Reid [68] found that in aviators, the near point of accommodation regresses with operational experience (number of sorties), and this, he argued, could be taken to indicate fatigue.

PROPRIOCEPTIVE SENSE

The possible existence of a proprioceptive sense from the extrinsic muscles of the eyes is an important problem in physiologic and psychologic optics. Such a sense has been postulated from time to time to explain stereoscopic vision, absolute distance, localization of objects, apparent location of objects in the visual field (asymmetrical convergence), a stimulus to accommodation,[69] the stability of our visual world in spite of eye movements,[70] etc. The difficulty with the hypothesis was that no sensory nerve endings in the muscles of the eye had ever been observed histologically. In a review of the literature on the problem, Irvine and Ludvigh (1936) concluded that there was no reliable evidence that proved the existence of this sense

66. Ogle.[36] Ogle, K. N.; Mussey, F., and Prangen, A. deH.: Fixation Disparity and the Fusional Processes in Binocular Single Vision, Am. J. Ophth. **32**:1069-1087 (Aug.) 1949.

67. Berens, C., and Sells, S. B.: Experimental Studies of Fatigue of Accommodation, II, Am. J. Ophth. **33**:47-57 (Jan.) 1950.

68. Reid, D. D.: Visual Tests of Fatigue in Operational Flying, Brit. J. Social Med. **3**: 101-109 (July) 1949.

69. Tolone, S.: Sulla genesi propricettiva del riflesso oculare d'accomodazione, Acta neurol., Naples **3**:444-449 (April) 1948.

70. Bell, G. H., and Weir, J. B. de V.: Vision During Glancing Movements of the Eyes, Tr. Ophth. Soc. U. Kingdom **67**:221-228, 1947.

from the extrinsic muscles. Yet many phenomena are difficult to account for except on the assumption of some type of proprioceptive sense. To avoid a specific hypothesis of a true myosensory effect, some authors [71] postulate, instead, a sensory component of the innervations sent to the extrinsic muscles.

Recently Cooper and Daniel [72] have reported finding definitely for the first time the existence of proprioceptive end organs in all the extrinsic muscles of human eyes. These muscle spindles are observed only in certain regions of the muscles, but the number found is comparable to the number found in the lumbricales muscles of the human hand. All rectus muscles are richly supplied with these spindles, especially the inferior rectus. Only the oblique muscles and the levator palpebrae are poorly supplied. The muscle spindles of the eye muscles differ from those of the exposed skeletal muscles of the body in that they have very delicate capsules and are generally smaller than those of the skeletal muscles. The function of these muscle spindles must be similar to that of the muscle spindles of the other body muscles. Irvine [73] summarizes:

> . . . the proprioceptive sense of the eye muscles might be relegated to a vague orienting of the position of the eyes to the position of the head, with as Chavasse suggested an increasingly greater effect as it is reinforced by other reflexes.

PHYSIOLOGIC NYSTAGMUS

The evidence that small involuntary oscillatory movements of the eyes exist continuously in spite of one's effort to hold accurate fixation is now well known. These movements appear as three types: (1) rapid drifts of fixation of 3 to 4 minutes of arc occurring about twice per second; (2) waves of small shifts and recoveries of about 2.5 minutes of arc at a rate of 5 per second, and (3) fine vibratory movements of about 2 minutes of arc at a rate of 50 to 100 per second. More recently, by photographing the movements of the image reflected from a small mirror attached to a contact lens over the eye, Riggs and Ratliff [74] found "flutter" movements during optimal fixation that have a mean excursion of 18 seconds of arc with frequencies of 30 to 70 cycles per second.

Of special interest is the possible effect of involuntary eye movements on binocular vision. Vukovich and Schubert [75] suggest that the phenomenon of Panum's fusional areas is due entirely to these movements. In support of this suggestion is the fact that the angular extent of Panum's areas in the horizontal meridian at the macula is of the same order of magnitude as the average larger drifts from accurate fixation. However, the extent to which these movements can account for Panum's areas depends on the extent to which they are random in the two eyes and are disjunctively coordinated. If these movements are conjugately coordinated, they cannot account for these fusional areas. Recent experimental evidence,[48] moreover, shows that most of the larger of these movements are conjugately coordinated;

71. Cogan, D. G.: Neurology of the Ocular Muscles, Springfield, Ill., Charles C Thomas, Publisher, 1948, p. 25.

72. Cooper, S., and Daniel, P. M.: Muscle Spindles in Human Extrinsic Eye Muscles, Brain **72**:1-24 (March) 1949.

73. Irvine, S. R.: New Evidence Relating to Proprioceptive Sense in the Extrinsic Eye Muscles, editorial, Am. J. Ophth. **33**:479-481 (March) 1950.

74. Riggs, L. A., and Ratliff, F.: The Steadiness of the Eye, abstracted, J. Optic. Soc. America **39**:630 (July) 1949.

75. Vukovich, V., and Schubert, G.: Fixationsschwankungen und binokulares Einfachsehen, von Graefes Arch. Ophth. **149**:706-718, 1949.

only the finest of these movements, the tremors, show no coordination in the two eyes. Apart from this evidence, however, is the fact that data [76] show a marked and rapid increase in the size of Panum's areas away from the maculas toward the peripheries of the retinas, and this fact cannot be accounted for by a physiologic nystagmus.

Hartridge and Weale [76] suggest that the scintillation of the stars is due to these involuntary eye movements. However, this possibility has been attacked from many sides, it being pointed out that scintillation varies with high and low altitudes and does not occur in the tropics, that some heavenly bodies scintillate (Sirius), while others do not (Saturn), etc.

CORNEAL-RETINAL POTENTIAL

Using a contact lens to support an electrode, Riggs and collaborators [77] have carefully measured the corneal-retinal potential with light excitation of the eye. The spectral sensitivity in electrical responses was determined in the dark-adapted eye and in the light-adapted eye, and these results were compared with the conventional brightness-matching experiments. In every case a spectral sensitivity curve, representing the minimal energy for retinal response from various dominant wavelengths of filtered light, was found. In comparison with the psychophysically determined curves, it appears that the electrical data fit the scotopic sensitivity curve more closely than they fit the photopic curve. The conclusion is that the principal component of the action potential of the human retina is initiated by the scotopic system of the eye. Johnson,[78] by a similar technique, studied the course amplitude of the b-wave (scotopic component) in the process of the eye's becoming dark adapted. An increase in amplitude to the test flashes of light from a stimulus area increased during the dark adaptation time. Curves giving the intensity for a given amplitude of b-wave response plotted against time are similar to the usual psychophysical curves. Dark adaptation curves have also been determined electroretinographically by the threshold method [79] in the rabbit and pigeon.

Under controlled conditions Fenn and collaborators [80] measured the corneal-retinal potential in anoxia and acapnia (diminished carbon dioxide in blood). Anoxia increases the potential, but this is ascribed largely to overventilation. Acapnia causes about a 20 per cent increase in potential.

The electrical setup for measuring eye movements by utilizing the effect of the corneal-retinal potential, a method which has been used for some time, is described by Powsner and Lion.[81] Electrodes are placed on opposite temples, and they receive

76. Hartridge, H., and Weale, R.: The Scintillation of Stars, Nature, London **164**:999-1000, 1949.

77. Riggs, L. A.; Berry, R. N., and Wayner, M.: A Comparison of Electrical and Psychophysical Determinations of the Spectral Sensitivity of the Human Eye, J. Optic. Soc. America **39**:427-436 (June) 1949. Riggs, L. A., and Johnson, E. P.: Electrical Responses of the Human Retina, J. Exper. Psychol. **39**:415-424 (Aug.) 1949.

78. Johnson, E. P.: The Electrical Response of the Human Retina During Dark-Adaptation, J. Exper. Psychol. **39**:597-609 (Oct.) 1949.

79. Waters, J. W.: Electroretinography of Experimental Animals, Brit. J. Ophth. **34**:1-15 (Jan.) 1950.

80. Fenn, W. O.; Galambos, R.; Otis, A. B., and Rahn, H.: Corneoretinal Potential in Anoxia and Acapnia, J. Appl. Physiol. **1**:710-716 (April) 1949.

81. Powsner, E. R., and Lion, K. S.: Testing Eye Muscles, Electronics **23**:96-99 (March) 1950.

a voltage depending on the angular position of the eyeballs. The rate of movement of the eyes will be proportional to the muscular forces moving the eyes. The setup is suggested for clinical studies.

STEREOPSIS

Many experiments have been performed which show that stereoscopic depth perception results from almost instantaneous presentation of the test pattern. Usually these test patterns have been pictures or drawn figures used in the haploscope or stereoscope. Smith [82] reduced the pattern for a stereoscopic test to three point light sources in total darkness. The points were arranged in six different patterns of depth differences from the eyes, and each pattern was presented to the subject for only 1/60 second. Nearly 90 per cent of the observations were correct responses; from this result Smith concluded that proprioceptive cues for stereoscopic perception were ruled out; disparity of retinal images is sufficient.

The three rod test for stereopsis was modified by Best [83] in that the two outer rods were replaced by two flat surfaces in the frontoparallel plane with the inner edges corresponding to the position of the outer rods. The central rod was adjustable forward and backward by rack and pinion, as before. The test was conducted at an observation distance of 5 meters with a rod length of 12 cm. Twenty settings were made. As usual, a constant error in the position of the central rod when it appears to be at the same distance as the edges is attributed to the horopter deviation.[36] Reduction of slit width, of course, reduces this effect. Highest stereoacuity was found for a slit width corresponding to a visual angle of 17 minutes of arc. It was found that in terms of mean variation of settings, the stereoacuity of 66 per cent of the subjects was 1.5 to 5.4 seconds of arc; of 27 per cent, 5.9 to 13 seconds of arc, and of 7 per cent, 16 to 21 seconds of arc. Heterophoria had no influence. Using the Verhoeff type of test, Jonkers [84] estimated that 24.7 seconds of arc could be taken as the upper limit for the normal binocular disparity for stereoscopic vision, although the median for 100 normal subjects (vision better than 5/5) was 16.4 seconds of arc. The standard deviation was not given.

The influence of practice on the stereoscopic sensitivity is important. Van Beuningen [85] found after a two week period of practice that the stereoscopic sensitivity was increased 30 to 50 per cent (60 subjects) on the three rod test; about 25 per cent (1,000 subjects), on the Pulfrich stereoscopic test; 60 per cent (60 subjects), on the Zeiss horopter apparatus, and 20 per cent (60 subjects), on the Monjé stereoeidometer. (The Monjé test is basically the three rod test in which the three rods are mounted in a rotatable ring in the frontoparallel plane. For a given displacement of the center of the three rods, the ring is rotated until stereopsis can or cannot be observed. The angle from the vertical, since the horizontal disparity would correspond to the cosine of this angle, is taken as a measure of the

82. Smith, S.: A Further Reduction of Sensory Factors in Stereoscopic Depth Perception, J. Exper. Psychol. **39**:393-394 (June) 1949.

83. Best, F.: Zur Prüfung des stereoskopisch-rämlichen Sehens, von Graefes Arch. Ophth. **149**:413-430, 1949.

84. Jonkers, G. H.: Some Data Concerning Verhoeff's Quantitative Test for Measuring the Acuity of Binocular Stereopsis, Ophthalmologica **118**:182-193 (March) 1949.

85. van Beuningen, E. G. A.: Die Änderungen von Sinnesleistungen durch Übung in ihrer Bedeutung für klinisch-ophthalmologische Untersuchungen, von Graefes Arch. Ophth. **149**: 460-489, 1949.

stereopsis.) The greatest improvement occurred during the first four to five days; afterward the improvement was slight.

An adaptation of the three rod (needle) test was used by Wagner [86] to determine the exposure time threshold for stereoscopic vision. At a distance of 6 meters the central rod was covered but could be exposed by a variable episcotister, while the outer two rods were seen constantly in binocular vision. For a given time of exposure, the minimal displacement of the central needle for a stereoscopic response was determined. The thresholds decreased rapidly with increase of exposure time until a minimal value was reached, beyond which increased time of exposure did not lower the threshold. For 14 subjects the exposure time for this minimal value varied from 70 to 350 milliseconds, the median being 210 milliseconds. By a similar method, Vilmar [87] determined the time threshold for stereoscopic vision in the peripheral parts of the retina. In 28 subjects the change of shortest exposure time for maximal stereoacuity was as follows: from 0 to 5 degrees, a 10 per cent increase in threshold; from 5 to 10 degrees, a further increase of 3 per cent; from 10 to 15 degrees, a further increase of 25 per cent, giving a total of a 38 per cent increase in threshold from 0 to 15 degrees. The increase was greater for retinal distances above the foveas than for distances nasally or temporally.

A comparison of stereoacuities with vernier acuities [88] shows the latter to be less influenced by changes in illumination than the former. The most marked decrease in threshold was between 0.04 and 10 millilamberts. Retinal resolution seems to be the essential factor at low levels of illumination, but at high levels other differential factors may also be involved. For the two rod test at 462 cm., the ratio of the vernier threshold to the stereoscopic threshold was 2.68: 3.39 seconds of arc. Changing the thickness of the rods did not significantly affect either the vernier or the stereoscopic threshold.[89]

The fact that the stereoscopic perception of space can be deformed by altering the images in the two eyes by glass plates, lenses or prisms is discussed by Cibis and Kolter.[90] In particular, the use of thick plane-parallel plates of glass inclined to the visual axis for near vision is shown to cause an apparent displacement of the position of objects seen through them. This may also cause an apparent enhancement of stereoscopic acuity. The effects observed are entirely accounted for in terms of the geometric and optical relations involved. This particular experiment is, of course, an aspect of the general problem of the distortion of stereoscopic spatial perception, which has been recently summarized by Ogle.[36]

THE PULFRICH STEREOPHENOMENON

If a pendulum is swinging freely in the frontoparallel plane of an observer in normal surroundings, and a dark glass is placed before one eye so as to reduce the intensity of the retinal image in that eye, the pendulum no longer appears to swing

86. Wagner, E.: Die Zeitschwelle der Tiefensehschärfe, Klin. Monatsbl. Augenh. **114**: 557-562, 1949.

87. Vilmar, K. F.: Die Zeitschwelle der Tiefensehschärfe in der Netzhautperipherie, Klin. Monatsbl. Augenh. **117**:242-248, 1950.

88. Berry, R. N.; Riggs, L. A., and Duncan, C. P.: The Relation of Vernier and Depth Discriminations to Field Brightness, J. Exper. Psychol. **40**:349-354 (June) 1950.

89. Berry, R. N.; Riggs, L. A., and Richards, W.: The Relation of Vernier and Depth Discrimination to Width of Test Rod, J. Exper. Psychol. **40**:520-522 (Aug.) 1950.

90. Cibis, P., and Kolter, R.: Über die Deformierung des Wahrnehmungsraumes durch Medien mit wegfremdem Brechungsindex, von Graefes Arch. Ophth. **150**:279-300, 1950.

in a plane but the end of the pendulum appears to move in an ellipse-like curve. The effect is thought to be due to the difference in reaction (perception) times of the visual processes in the two eyes, a reaction which varies with illumination. The difference in arrival time of the nervous impulses from the two eyes at the cortical areas is a stereoscopic experience. By placing suitable markers before and behind the pendulum, the actual amount of the apparent depth effect can be measured. The literature on the subject is voluminous. Recently Wagner [91] found the phenomenon highly repeatable, and uninfluenced by environmental factors, such as time of day or clear or overcast sky. He had some evidence that fatigue tended to increase the stereoeffect. The apparent distance behind the plane of the pendulum is always greater than that before the plane. This is explained on the basis of the geometric relations involved, in that for a given angular disparity between the images of the two eyes the depth difference behind the fixation point must always be greater than that in front. Of course, there must be other details and empirical cues in the field of view for the effect to occur.

The perception (reaction) time is believed to obey Weber's law in its dependence on illumination. Best [92] studied the stereoeffect, in terms of constant adaptation of the eye, on the luminous intensity given to either eye. The difference in illumination to the two eyes necessary to produce the same stereoeffect decreased with the lower general illumination, but less than that demanded by Weber's law. Best concluded that this difference is due to the decreased stereoscopic sensitivity with lowered illumination.

Fischer and Kaiser [93] arranged a stimulus to move back and forth in a line, the speed of which varied sinusoidally, like that in a pendulum in motion. The line of movement could be varied from the horizontal to the vertical meridian. In the horizontal, when a dark glass was placed before one eye, the usual stereoeffect was observed and measured. When the line of movement is inclined, one would expect that the amount of stereoeffect would decrease according to the cosine of the angle of inclination, being zero in the vertical. Data showed the effect to decrease more rapidly than was expected at first and then more slowly, and the decrease to differ from the cosine function. The investigators concluded that the Pulfrich effect depends on factors other than simply stereopsis and difference in reaction times of the two unequally illuminated eyes.

SPACE PERCEPTION

No attempt will be made at this time to review papers that have appeared on this subject. Suffice it to say that these papers have in the main been concerned with the size constancy phenomenon and its ramifications.[94] Attention is called to the

91. Wagner, E.: Beobachtungen zum Pulfrich-Effekt, Klin. Monatsbl. Augenh. **115**:143-149, 1949.

92. Best, W.: Pulfrich-Effekt und Webersches Gesetz, Arch. ges. Physiol. **251**:167-176 (April) 1949.

93. Fischer, M. H., and Kaiser, I.: Studien über den optischen Raumsinn I, Arch. ges. Physiol. **252**:331-344 (March) 1950.

94. Joynson, R. B.: The Problem of Size and Distance, Quart. J. Exper. Psychol. **1**: 119-135 (March) 1949. Hastorf, A. H.: The Influence of Suggestion on the Relationship Between Stimulus Size and Perceived Distance, J. Psychol. **29**:195-217 (Jan.) 1950. Schlosberg, H.: A Note on Depth Perception, Size Constancy, and Related Topics, Psychol. Rev. **57**:314-317 (Sept.) 1950.

new book by Gibson [95] in which the author elaborates the hypothesis that spatial localization depends on the perception of "gradient" in the retinal images—for example, the gradient in the texture of surfaces as they recede into the distance. Even the size constancy phenomenon is explained on the basis of this perception (as a gestalt perception) of image gradients.

THE LIGHT SENSE

The subjective observation of one's own fovea, by observing the after-image against a gray background, has been discussed by several authors. Miles,[96] with the use of special filters, measured details within the fovea by this method. In normal eyes a central area about 30 minutes of arc in diameter appears functionally different from the surrounding areas. Kellershohn [97] observed the after-image of a bright cross. After one to three minutes the center of the after-image, which measures 1.5 to 1.7 degrees, vanishes. This "hole" is assumed to correspond to a rod-free area of the fovea. The phenomenon is best observed with blue light and does not occur with red light. Brückner,[98] similarly, has observed this phenomenon in that the yellow spot in the visual field produces a blue-violet after-image.

HAIDINGER BRUSHES

If one views a uniformly illuminated surface through polaroid® or a Nicol prism, in suitable circumstances, one observes around the fixation point a yellow and a blue "brush" or "sheaves" (shaped like the sheaves of wheat) with center at the fixation point. The yellow brushes are parallel to the plane of polarization; the blue ones, perpendicular to this plane. These brushes, known as Haidinger brushes, are sometimes difficult to see but are more easily seen in blue light than in light of other colors and hence are more easily seen against the sky than against another background. The brushes appear to rotate with rotation of the polarizing screen. This phenomenon is a specialized entoptic image of the fovea. It is probably due to the birefringent properties of Henle's fiber layer,[99] though Stanworth and Naylor [100] advance the hypothesis that the brushes are due to dichrotic properties of the blue receptors of the macula. Goldschmidt [101] has devised a lantern test with which he claims 100 per cent of persons can definitely recognize these brushes. He has found the instrument of clinical value for the testing of the function of the macula. The brushes are absent in albinos, when there is complete color blindness, degeneration of the macula, etc. In amblyopia, if the

95. Gibson, J. J.: The Perception of the Visual World, Boston, Houghton Mifflin Company, 1950.

96. Miles, W. R.: On the Central Zone of the Human Fovea, Science **109**:441-442 (April 29) 1949.

97. Kellershohn, C.: Une méthode de mesure physiologique des dimensions de la fovea, Compt. rend. Soc. biol. **143**:210-211 (Feb.) 1949.

98. Brückner, A.: Über die entoptische Sichtbarkeit des gelben Fleckes, Wien. med. Wchnschr. **100**:30-31, 1950.

99. Gording, E. J.: A Report on Haidinger Brushes, Am. J. Optometry **27**:604-610 (Dec.) 1950.

100. Stanworth, A., and Naylor, E. J.: Haidinger's Brushes and the Retinal Receptors, with a Note on the Stiles-Crawford Effect, Brit. J. Ophth. **34**:282-291 (May) 1950.

101. Goldschmidt, M.: A New Test for Function of the Macula Lutea, Arch. Ophth. **44**: 129-135 (July) 1950.

brushes are apparent, it may be possible to predict whether occlusion and orthoptic training will be of value.

DARK ADAPTATION

After the eyes have been exposed to a bright light, the subject is placed in a dark room. At various time intervals the threshold intensity of light in order to be perceived is obtained. The resulting curve, showing the decrease in threshold intensity with time in the dark, is the dark adaptation curve. By suitable fixation point and color filters, these curves can be determined for (macular) cone or (peripheral) rod vision. Recent measurements on a large number of observers [102] have shown that there is no correlation between age and the rate of either cone or rod adaptation, but the thresholds at the end of six and 26 minutes are significantly related to age, the threshold being higher in the older than in the younger subjects. Auerswald and collaborators [102b] determined the frequency distribution of dark adaptation thresholds, using 353 subjects. The thresholds of emmetropes proved to have a normal distribution, those of the ametropes less so. The thresholds were significantly higher in older than in younger subjects. Auerswald and collaborators [102b] developed statistically a means for finding the position of the dark adaptation threshold of a single subject in the frequency distribution. The resulting "valuation number" can serve as a guide for diagnostic estimation of dark adaptation data.

Sloan [103] determined the cone and rod thresholds in the dark-adapted eye, taking special pains to correct the values for the rod determinations in the periphery for the effective areas of the pupil (determined photographically). She found the rod threshold inversely proportional to the areal density of the rods. This result suggests a summation of receptor impulses. This relationship was not found for cone thresholds. In perimetry, under conditions of complete or partial dark adaptation a test object of low brightness is necessary if isolated areas of rod involvements are to be detected.

Nearly 50 years ago Sherrington, in flicker experiments, showed that the critical flicker frequencies for monocular and binocular in-phase impulses were not statistically different and concluded that there is no interaction between the two eyes. Ireland [104] has recently devised a greatly improved instrument utilizing electronic mechanism to improve and control accuracy. The critical flicker frequency was determined [105] monocularly (dominant and nondominant eyes), and binocularly (in-phase and out-of-phase flicker to the two eyes), for 24 subjects. The results show definitely that the critical flicker frequency with binocular in-phase impulses is statistically significantly higher than monocular critical flicker frequency, and that the critical flicker frequency with binocular out-of-phase impulses is lower than monocular critical flicker frequency. The conclusion is that some postulate regarding an interaction of the two eyes is necessary—probably as a central process.

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102. (*a*) Birren, S. E., and Shock, N. W.: Age Changes in Rate and Level of Visual Dark Adaptation, J. Appl. Physiol. **2**:407-411, 1950. (*b*) Auerswald, W.; Bornschein, H., and Zwiauer: Die physiologische Variationsbreite als statistische Bewertungsgrundlage der Dunkeladaptation, von Graefes Arch. Ophth. **150**:301-316, 1950.

103. Sloan, L. L.: The Threshold Gradients of the Rods and the Cones: In the Dark-Adapted and in the Partially Light-Adapted Eye, Am. J. Ophth. **33**:1077-1089 (July) 1950.

104. Ireland, F. H.: An Electronic Flicker Apparatus for Monocular and Binocular Stimulation, J. Psychol. **29**:183-193 (Jan.) 1950.

105. Ireland, F. H.: A Comparison of Critical Flicker Frequencies Under Conditions of Monocular and Binocular Stimulation, J. Exper. Psychol. **40**:282-286 (April) 1950.

Ophthalmological Reviews

MEASUREMENT OF VISUAL ACUITY

A Critical Review

LOUISE L. SLOAN, Ph.D.
BALTIMORE

THE PURPOSE of this review is to investigate the relative merits of different test objects and procedures used to measure visual acuity, with particular emphasis on their suitability as selection tests for industry, the military services, etc., and as screening tests for the detection of errors of refraction or other visual defects. Adoption of a standard procedure for the measurement of individual differences in acuity which gives valid and precise measures and is at the same time simple and practical requires consideration of the following points: (1) selection of the most suitable type of test object; (2) specification of the range and gradation of the sizes of test object required, and (3) standardization of the brightness of test object and background and of other variable factors in the test procedure.

RELATIVE MERITS OF DIFFERENT TYPES OF TEST OBJECTS

In an excellent review Cowan [1] described the numerous variations of test objects used or recommended prior to 1928. More recent developments include the checkerboard target, first proposed by Goldmann [2] in 1943 and now used in the Bausch & Lomb Ortho-Rater.[3] Ferree and Rand,[4] in 1940, and Fink,[5] in 1945, suggested the use of ring test objects with multiple openings.

In investigations of the resolving power of the retina itself rather than of the optical system of the eye, focused retinal images are obtained by the use of a small artificial pupil or by correction of errors of refraction by means of suitable lenses. For such studies a determination of the minimum visual angle at which two points or two lines can be resolved is preferable to the use of more complex test objects requiring discriminations which may depend in part on factors other than visual acuity. The tests of acuity employed by the ophthalmologist and the optometrist and those used in industry, in the military services, etc., to determine fitness for certain tasks are, on the other hand, specifically designed to detect impairment of acuity caused in the great majority of cases by errors of refraction. Consideration

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1. Cowan, A.: Test Cards for Determination of Visual Acuity, Arch. Ophth. **57**:283 (May) 1928.

2. Goldmann, H.: Objektive Sehschärfenbestimmung, Ophthalmologica **105**:240, 1943.

3. Bausch & Lomb Optical Company: Administration of the Bausch & Lomb Occupational Vision Tests with the Ortho-Rater, 1944.

4. Ferree, C. E. and Rand, G.: More Nearly Absolute Method of Testing and Rating Vision, Arch. Ophth. **24**:292 (Aug.) 1940.

5. Fink, W. H.: Evaluation of Visual Acuity Symbols, Am. J. Ophth. **28**:701 (July) 1945.

of the tasks set by the simpler test objects suggests that in astigmatic errors acuity may be overestimated. A subject with a simple hypermetropic astigmatism at axis 180 degree, for example, can successively focus vertical and horizontal contours. The orientation of a parallel bar test object or of Snellen's E may therefore be judged correctly, although all parts of the test object are not clearly focused. In the checkerboard target of the Bausch & Lomb Ortho-Rater, when the image is out of focus in either the vertical or the horizontal meridian, the checkerboard pattern appears as a series of light and dark bars, which should be easily distinguished from the confusion squares. The effects of simple astigmatism on the Landolt and other ring test objects are more difficult to predict because of the curved contours.

The hypothesis that the simple test objects may overestimate acuity is supported by the results of Fry's experiments. Fry [6] measured the distribution of light in blurred images simulating those of the astigmatic eye. The test objects studied were single and multiple bars, a checkerboard and a Landolt ring. A similar study of the blurred images of letter targets would be of value and might be supplemented by more direct experimental data providing a comparison of the acuities for simple and complex test objects of subjects having uncorrected astigmatic errors.

The case for test objects of complex form is clearly presented by Emsley.[7] Test characters used to determine the best optical correction of the eye should be, he states, "of as complicated form as is clinically convenient in order to subject the eye to a test comparable with the varied tasks imposed upon it in every day life. At the same time, however, the test should permit of simple questions to and simple answers from the subject; and his answers should be capable of rapid checking. To make the test precise the characters should quickly become unrecognizable when not seen clearly." Emsley's requirements are also applicable to screening and to selection tests requiring measurements of acuity of subjects with uncorrected errors of refraction. For this purpose, the ideal test object should contain horizontal, oblique, vertical and curved contours, such that it can be recognized only when clearly focused in all meridians. Since the response to such complex forms must necessarily be in terms of recognition, suitably chosen letters or numbers are the obvious choice for literate adults. For subjects unfamiliar with letters or numbers some one of the simpler test objects, such as the Landolt ring, must be used.

When complex test characters are employed as measures of acuity, the assumption is usually made that recognition of the familiar letter or symbol requires resolution of its component parts. Acuity is therefore measured in terms of the visual angle subtended by the constituent parts of the test target. In an attempt to standardize the difficulty of recognition, Snellen [8] in 1862 devised his well known letters, in which the width of the black strokes is equal to the white spaces between them and the letters are enclosed in a square whose sides are five times the width of the letter strokes. Serifs are added to the longer strokes in order to maintain the unit separation of black and white areas throughout the letter. It has been shown,[9]

6. Fry, G.: Significance of Visual Acuity Measurements Without Glasses, Am. J. Optometry **25**:199, 1948.

7. Emsley, H. H.: Visual Optics, London, Hatton Press, Ltd. 1936, p. 53.

8. Snellen, H.: Probebuchstaben zur Bestimmung der Sehschärfe, Utrecht, P. W. van de Weijer, 1862.

9. (*a*) Dennett, W. S.: Test Type, Tr. Am. Ophth. Soc. **4**:133-139, 1885. (*b*) LeGrand, Y., and Guillemot, E.: Measurement of Visual Acuity with Blurred Tests, Nature **159**:132 (Jan. 25) 1947.

however, that the different Snellen letters are by no means equal in difficulty. This is in part because certain letters are more easily recognized than others by their general form before the component parts are clearly distinguished. Dennett [9a] pointed out that even though the unit width of strokes and spaces is maintained, some letters present larger areas of blackness where the strokes join or cross one another.

A number of investigators [10] have recommended selections of letters, based either on Snellen's design or on modifications of it, which they hoped would be approximately equal in difficulty. The most radical change from the Snellen type of letter is that proposed by Dennett,[9a] who recommended characters in which the entire letter is much larger than its component parts. All the places where one line crosses another may therefore be cut out without destroying the general shape of the letter. According to Dennett, its visibility should therefore depend entirely on the width of the lines. Figure 1 illustrates several such letters. Many of these investigations offer no experimental evidence to support their claims that the recommended letters actually are equal in difficulty. Studies which provide such data [11] show clearly that the letters chosen are actually far from equal. This is true even when the subjects tested have only minor uncorrected errors of refraction. In a group of subjects with different degrees and types of refractive error it is to be expected that certain letters will be relatively difficult for one subject and relatively easy for another. The results of these studies indicate that strict adherence to the Snellen principle of letter formation does not necessarily insure equal legibility. In fact, for certain letters the use of serifs may produce characters particularly difficult to recognize because of their unfamiliar forms.

The Landolt ring was adopted in 1909 by the Eleventh International Ophthalmological Congress [12] as the standard test object. At least two possible objections to its use should be considered. First, it perhaps overestimates the acuity of the subject with an uncorrected astigmatism. In spite of its apparently simple form, however, its curved contours may make it more difficult for such subjects than other simple test objects, such as parallel bars and checkerboards. This question can be answered only by making comparative measures of acuity with Landolt rings and with more complex test targets, such as letters having vertical, horizontal, oblique

10. (*a*) Oliver, C. A.: A New Series of Metric Test Letters for Determining the Acuity of Direct Vision for Form, Tr. Am. Ophth. Soc. **4**:130, 1885. (*b*) Jackson, E.; Black, N. M.; Ewing, A. E.; Lancaster, W. B., and Fagin, R.: Committee on Standardizing Test Cards for Visual Acuity, Tr. Sect. Ophth. A. M. A., pp. 383-388, 1916. (*c*) Jackson, E.; Fagin, R., and Lancaster, W. B.: Committee on Standardizing Test Cards, ibid., pp. 347-349, 1917. (*d*) Hay, P. J.: Notes on Some New Test-Types, Including a Note on Coloured Test-Types, and Their Application to Toxic Amblyopia, Tr. Ophth. Soc. U. Kingdom **39**:240, 1919. (*e*) Hartridge, H., and Owen, H. B.: Test Types, Brit. J. Ophth. **6**:543, 1922. (*f*) Cowan, A.: Test Letters Which Comply with Physiological Requirements of Visual Test Object, Tr. Am. Ophth. Soc. **26**:260, 1928. (*g*) Banister, H.: Block Capital Letters as Tests of Visual Acuity, Brit. J. Ophth. **11**:49 (Feb.) 1927. (*h*) Walker, J. P. S.: Test Types, ibid. **26**:556, 1942. (*i*) United States Adjutant General's Department: Studies in Visual Acuity, prepared by staff, Personnel Research Section, Army Department, Personnel Research Section Report 742, United States Government Printing Office, Washington, D. C., 1948.

11. Jackson, Black and others.[10b] Jackson, Fagin and Lancaster.[10c] Hartridge and Owen.[10e] Banister.[10g] Adjutant General's Department.[10i]

12. Cited by Cowan,[1] p. 292.

and curved contours. A second objection to the Landolt ring is a practical rather than a theoretical one, which will be recognized by anyone who has used both this and letter test objects extensively in the routine testing of visual acuity. After such experience it is obvious that more attention and concentration are required of the examiner in checking the correctness of the subject's responses to Landolt rings, whose breaks are in any one of four positions, than is required in checking the responses when a group of about 10 different letters are to be read. Many subjects, when they reach a line of test characters which they can recognize only with difficulty, read the first three or four and then without any warning to the examiner go back to the beginning of the line of test objects. In a line composed of 10 different letters it is not difficult for the examiner to know that this has happened, but he may become hopelessly confused in trying to keep track of the answers of up, down, right, up, left, right, etc., given by the subject in locating the openings in a series of Landolt rings. This practical difficulty can, of course, be overcome if the examiner

Fig. 1.—Letters suggested by Dennett[9a] for the measurement of visual acuity.

points to each character in turn, and it may not arise in laboratory studies in which both the examiner and the examinee are highly motivated. The reality of this objection to the Landolt ring and to other test targets in which the subject's response fall into only four categories is perhaps demonstrated by the fact that, in spite of recommendations in its favor, it has been used by ophthalmologists only in research studies. Committees of the American Medical Association[13] in 1916 and in 1930 upheld the scientific advantages of the Landolt ring but must have recognized its practical disadvantages, since they recommended for routine testing the use of letters whose relative difficulty had been previously determined by comparison with the Landolt ring.

As an immediate practical solution, it is suggested that familiar nonserif letters be used to measure visual acuity and that about 10 such letters be selected which by

13. (*a*) Jackson, and others.[10b] (*b*) Jackson, E., and others: Report of American Committee on Optics and Visual Physiology: Report on the Tests and Records of Visual Acuity, Tr. Sect. Ophth. A. M. A., pp. 358-363, 1930.

experiment are found not to differ markedly in legibility. If this same group of letters is used on each line of the acuity chart, the average difficulty of each line as a whole will vary only with the size of its letters. For convenience, acuity may be rated as usual in terms of the visual angle subtended by the component parts of the smallest line of letters which can be recognized. This provides a standard, though arbitrary, measure of the minimum visible. It is not necessarily equal to the minimum visible for other test targets, or even for a different selection of letters.

UNITS FOR SPECIFICATION OF VISUAL ACUITY

The simplest and most direct method of specifying visual acuity is to give the threshold visual angle directly in minutes. Acuities of 20/20, 20/30 and 20/40 in Snellen notation, for example, correspond to thresholds of 1.0, 1.5 and 2 minutes, respectively. In accordance with other physiological measures in which sensitivity or capacity to respond is defined as proportional to the reciprocal of the threshold stimulus, visual acuity has also been defined as proportional to the reciprocal of the minimum discriminable visual angle, i. e., $V = C/A$. If A is expressed in minutes and the constant C is assigned a value of unity, then $V = 1.00$ when the minimum angle equals 1 minute. Although it is now recognized that average normal acuity is greater than 1.00 for commonly used test objects, levels of illumination, etc., it is nevertheless convenient to retain the simple formula, $V = 1/A$, with the understanding that an acuity of 1.00 represents an arbitrary standard level which happens to be close to average normal acuity under ordinary conditions. Snellen introduced the formula $V = d/D$, in which d equals the distance at which the test object can just be resolved and D, the distance at which its component parts subtend a 1 minute visual angle. Snellen's equation can be derived from the more fundamental formula $V = 1/A$, since it can be shown that $A = D/d$. The Snellen formula is the more convenient to use when the testing distance is not kept constant, since each size of test object may be specified not in terms of the visual angle its parts subtend at some fixed distance but in terms of the distance, D, at which they subtend the standard value of 1 minute.

While Snellen's notation has been generally adopted, many, including Snellen himself, do not accept its fundamental basis. Snellen stated that the fraction d/D should not be reduced to a decimal because the decimal notation leads to erroneous conclusions and suggests that an acuity of 20/40, or 0.5, is only half as great as an acuity of 20/20. Those who object to the decimal notation derived from the Snellen fraction do not accept the definition of acuity as inversely proportional to the threshold visual angle and consider the Snellen fraction as an arbitrary description of the results of a test of visual acuity without quantitative significance. Acceptance of the decimal notation, however, does not imply that its units necessarily represent equal steps of visual capacity. It should be pointed out that only by reducing the fraction to a decimal can we conclude, for example, that an acuity of 6/4 is superior to an acuity of 20/15.

The fact that Snellen,[14] in 1897, recommended that the sizes of letters on the test chart increase by a constant ratio, i. e., by equal steps on a logarithmic scale, suggests an implicit belief that degrees of visual capacity are proportional, not to

14. Snellen, H.: Methods of Determining the Acuity of Vision, in System of Diseases of the Eye, edited by W. F. Norris and C. A. Oliver, Vol. II, Philadelphia, 1897.

$1/A$, but to its logarithm. Since then, others [15] have recommended a logarithmic gradation of letter sizes. Although there are no experimental studies which give direct support to the assumption that visual capacity varies with the logarithm of the acuity, it has a certain reasonableness, in view of the fact that other sensory responses have been shown to be proportional to the logarithm of the stimulus. Snellen, Green and other ophthalmologists, although they advocated geometric gradation of letter sizes (equivalent to equal steps on a logarithmic scale), have nevertheless continued to use the Snellen notation for the specification of acuity. In the recent study conducted by the Adjutant General's Office,[101] however, not only is the logarithmic scale used to determine the gradation of letter sizes, but the acuities themselves are expressed in "AGO units," proportional to the logarithm of the threshold visual angle. Attempts have also been made to rate different degrees of acuity for the special purpose of determining economic usefulness. These units of "visual efficiency" are described in more detail in the next section.

The best method of specifying the findings on a test of visual acuity can perhaps be decided on the basis of its convenience, simplicity, etc. Specification of the threshold visual angle, though little used at present, gives direct and unequivocal information which may be used to convert the data to any other desired notation. For example, if the threshold visual angle is 5 minutes, the visual acuity in Snellen's notation is $\frac{20}{20 \times 5}$, or 20/100. Visual acuity in decimal notation is equal to the reciprocal of the visual angle. Thus, if the threshold visual angle is 5 minutes, the visual acuity is 1/5, or 0.2. Estimates of economic visual efficiency can, similarly, be obtained from specifications of the visual angle by means of a formula or a conversion table. Because of long usage, the Snellen form of notation is firmly established in the literature and conveys an immediate meaning to the ophthalmologist who has used it for many years. Whenever some other form of specification is used, perhaps because it lends itself better to statistical treatment of the data, it is therefore advisable that the equivalent Snellen notations be given as well.

GRADATION OF STEPS ON THE ACUITY CHART

As stated previously, the choice of a unit for specifying the results of a test of acuity is chiefly a question of convenience, since conversion from one unit to another is a simple matter. A closely related but more fundamental problem concerns the choice of a unit in which to grade the different sizes of letter on an acuity chart.

While there is agreement that for most purposes of the ophthalmologist and optometrist the range should extend from about 10 minutes (20/200) to less than 1 minute (better than 20/20), there is less agreement as to the number of sizes of test target needed between these limits and as to their gradation. Snellen [14] and others [16] believed the ideal gradation to be one in which the test targets increase in visual angle by a constant ratio, i. e., by equal steps on a logarithmic scale. Green,[15a] for example, suggested a ratio of approximately 1.26. Since the logarithm

15. (*a*) Green, J.: On a New Series of Test Letters for Determining the Acuteness of Vision, Am. Ophth. Soc. **1**:368, 1865-1871. (*b*) American Ophthalmological Society: Report of the Committee on Standard Test-Types and on Reading Tests, Tr. Am. Ophth. Soc. **10**:189, 1903-1905. (*c*) Green, J.: Notes on the Clinical Determination of the Acuteness of Vision, Including the Construction and Gradation of Optotypes, and on Systems of Notation, Tr. Am. Ophth. Soc. **10**:644-654, 1903-1905.

16. Footnote.[15] Tscherning, M.: Mesures de clarté, Acta ophth. **4**:12, 1927.

of 1.26 is 0.10, this scale is one in which the logarithm of the visual angle increases in steps of 0.1. It provides, therefore, 11 sizes between a 1 minute visual angle (0.0 log unit) and a 10 minute visual angle (1.0 log unit). Extension of the scale two steps below the 1 minute level requires visual angles of 0.8 and 0.6 minutes (— 0.1 and — 0.2 log units). These correspond to 20/16 and 20/12 in Snellen notation. The recent study conducted by the Adjutant General's Office employed a number of especially devised charts in which the visual angles varied by steps of 0.075 log unit from 20/40 to 20/7.1.

Equal steps of visual acuity on the so-called decimal scale (reciprocal of visual angle) have also been used.[17] A committee of the American Medical Association [13b] in 1930 recommended visual acuity charts with 10 equal steps on the decimal scale between 0.1 (20/200 and 1.0 (20/20) plus steps of 1.2, 1.5 and 2.0 (20/17, 20/13 and 20/10). In the Grow [18] and Lebensohn [19] charts, developed for the United States Navy, the letters are all of the same size, and increases in visual angle are obtained by decreasing the distance between observer and chart. At 20 feet the component parts of the letters subtend a visual angle of 1 minute (20/20). Decreases in the distance at which the letters can just be recognized, from 20 to 18, 16, 14 feet, etc., correspond to decreases in visual acuity on the decimal scale from 1.0 to 0.9, 0.8 and 0.7, respectively (in Snellen notation, from 20/20 to 18/20, 16/20 and 14/20). The acuity chart of the Bausch & Lomb Ortho-Rater [8] comprises 15 equal steps on a decimal scale ranging from 0.1 to 1.5.

The AAF Constant Decrement Test, one of those used in the study made by the Adjutant General's Department,[10f] is among the few acuity charts using gradation in equal steps of visual angle. This chart employs 36 target sizes between 20/40 and 20/5, i. e., 20/40, 20/39, 20/38, etc. The corresponding visual angles, 2.0, 1.95, 1.90, etc., decrease by equal amounts on a visual angle scale.

For the special purpose of measuring the loss of visual function from an economic point of view in order to determine compensation for eye injuries, a still different unit and scale may be needed to measure what is known as the "visual efficiency." The various proposals for estimating economic loss of vision all start by defining two end points, corresponding respectively to 0 and 100 per cent loss of visual efficiency, i. e., to economic blindness. An acuity of about 20/20 is generally accepted as representing no loss, and an acuity of 20/200 as complete loss, of visual efficiency. In order to estimate partial losses, Sharp [20] in 1920 divided the scale into equal steps on a visual angle scale, with 20/20 equal to no loss, 20/40 to 10 per cent loss, 20/60 to 20 per cent loss, etc. Lewis [21] in 1929 recommended a very similar scale for the estimation of loss of visual efficiency.

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17. Monoyer, H.: Echelle typographic décimale, 1877, cited by Cowan.[1] Weiss, L.: Sehproben-Tafeln zur Bestimmung der Sehschärfe für die Ferne, Heidelburg, 1895; cited by Cowan.[1] Von Blaskovics, L.: Über Verwendbarkeit von Buchstaben und Zahlen bei Sehschärfe-Untersuchungen, Klin. Monatsbl. Augenh. **71**:440, 1923.

18. Grow, E. J.: An "Unlearnable" Visiòn Test Card for Use in the Naval Service, U. S. Nav. M. Bull. **4**:357, 1910.

19. Lebensohn, J. E.: An Improved Unlearnable Letter Chart, Tr. Am. Acad. Ophth. **47**:127, 1942; Visual Rating and Presentation of Improved Unlearnable Letter Chart, U. S. Nav. M. Bull. **41**:744, 1943.

20. Sharp, W. N.: Loss of Industrial Vision, Am. J. Ophth. **3**:434, 1920.

21. Lewis, F. P.: Five Minute Angle as General Formula for Recording Visual Acuity, J. A. M. A. **93**:972 (Sept. 28) 1929.

Snell [22] in 1924 recommended equal logarithmic rather than equal arithmetical steps of visual angle. On his suggested scale, a threshold visual angle of 1.6 minutes (20/32) corresponds to 100 per cent visual efficiency, and a threshold visual angle of 16 minutes (20/320), to 0 per cent, and in general per cent of visual efficiency, E, is given by the formula $E = 100\ (1\text{-log } A/A_0)$, in which the constant $A_0 = 1.6$ minutes. Loss of visual efficiency by this formula therefore varies as the logarithm of the visual angle. In the following year Snell, in collaboration with Sterling,[23] proposed a quite different formula, which assumes that the logarithm of visual efficiency varies as the visual angle. Constants were so chosen that E equals 100 per cent when A equals one minute (20/20), and E equals 20 per cent when A equals 10 minutes (20/200).

The Snell-Sterling formula may therefore be written: $\log 100 - \log E = 0.078\ (A\text{-}1)$. Snell's previous formula was based on the assumption that visual efficiency decreases in equal steps with a constant increase in the ratio of the minimum visual angle. The new formula, on the other hand, states that with a constant increase in the minimum visual angle, visual efficiency decreases in a constant ratio. The experimental and logical bases for the Snell-Sterling formula are as follows: Etched

TABLE 1.—*Data from Snell and Sterling* [23]

No. of Etched Glasses	Assumed Per Cent Visual Efficiency	Observed Visual Acuity
0	100.0	20/20
1	83.3	20/40
2	66.7	20/65
3	50.0	20/100
4	33.3	20/160
5	16.7	20/250
6	0.0	20/400-20/600
7	....	Qualitative vision

glasses were constructed each of which, when used alone, reduced acuity from 20/20 to 20/40. When six such glasses were superimposed, there was almost total loss of visual perception. It was assumed, therefore, that each successive etched glass decreased visual efficiency by 1/6. Table 1 shows typical data giving actual acuities which were obtained with different numbers of the etched glasses in front of the eye.

These and similar observations agree approximately with the formula proposed by Snell and Sterling. The rating of visual efficiency is intended to be applicable to measures of corrected visual acuity in which impairment is the result of injury or ocular disease. It is assumed that the etched glasses closely simulate the effect on acuity of a corneal opacity or similar lesion. No consideration is given to the possibility that other types of ocular disease or injury may have quite different effects. In spite of the somewhat shaky experimental and logical foundations of the Snell-Sterling formula, it was recommended in 1925 and in 1941 by committees of the

22. Snell, A. C.: Mathematical Values of the Snellen Notations, Am. J. Ophth. **7**:227, 1924.

23. Snell, A. C., and Sterling, S.: The Percentage Evaluation of Macular Vision, Arch. Ophth. **54**:443 (Sept.) 1925; An Experimental Investigation to Determine the Percentage Relation Between Macular Acuity of Vision and Macular Perception, Contributions to Ophthalmic Science, George Banta Publishing Company, Menasha, Wis., 1926, pp. 52-62.

American Medical Association [24] as one of the formulas for computing economic visual disability and has apparently proved satisfactory for this purpose. Visual acuity charts graded in 5 per cent steps on the scale of visual efficiency are commercially available. Except for these charts and the acuity slides of the Ortho-Rater, none of the tests of visual acuity in common use in the United States follow exactly any consistent principle of gradation of size of test target.

The argument for equal steps on a logarithmic scale is based on the assumption that the increase in size of stimulus required to produce a just noticeable increase in discrimination is a constant fraction of the initial stimulus. This is Weber's law, which has been shown to hold approximately for the discrimination of differences in intensity of light and for many other sensory discriminations. While its application to space discrimination has never been experimentally demonstrated, it is reasonable to suppose that it may apply to the visual acuity of normal eyes whose errors of refraction have been corrected. If so, a gradation of test object sizes on a logarithmic scale between 20/20 and 20/10 might best measure the differences in retinal resolution among such normal subjects. Visual acuity below 20/20 occurs as a rule only when there is, for example, an uncorrected error of refraction, some interference with transmission of light associated with opacities of the refractive media or some pathologic condition of the retina, neural conducting mechanisms, etc. In an unselected population, uncorrected errors of refraction are the most frequent cause of reduction in acuity below 20/20. To detect impairment of acuity produced by error of refraction, the logical gradation of test character appears to be one determined by the rate of decrease in acuity corresponding to a constant increase in diopters of refractive error. For example, the gradation might be such that each 0.25 D. of myopia reduced acuity by one line on the test chart.

RELATIONSHIP BETWEEN ERROR OF REFRACTION AND VISUAL ACUITY

A number of studies have investigated experimentally the relationship between diopters of refractive error and visual acuity. Pincus [25] gave estimates based on data from over 7,000 eyes of the average acuity corresponding to each amount of refractive error. These were computed by averaging the denominators of the Snellen fractions and converting them to the nearest Snellen equivalent in round numbers. This procedure actually determines the average value of the minimum visual angle. Eggers [26] reported approximate estimates of the average refractive error associated with each level of visual acuity. These estimates were based on data for more than 6,000 subjects.

Hirsch [27] presented a more exact statistical analysis, which was, however, based on results for only 64 eyes. The data show a linear relationship between log acuity and log myopia. Hirsch's equation for the prediction of visual acuity (V) from the

24. Report of Snell, A. C.; Gradle, H. S., and Cowan, A.: Committee on Compensation for Eye Injuries, American Medical Association, Tr. Sect. Ophth. A. M. A., pp. 368-377, 1925; Report of Committee on Visual Economics, ibid., pp. 329-337, 1941.

25. Pincus, M. H.: Unaided Visual Acuities Correlated with Refractive Errors, Am. J. Ophth. **29**:853 (July) 1946.

26. Eggers, H.: Estimation of Uncorrected Visual Acuity in Malingerers, Arch. Ophth. **33**:23 (Jan.) 1945.

27. Hirsch, M. J.: Relation of Visual Acuity to Myopia, Arch. Ophth. **34**:418 (Nov.-Dec.) 1945.

amount of myopia (M) is: $\log V = 1.360 \log M + 1.817$. The correlation coefficient of 0.95 between $\log V$ and $\log M$ indicates a very close relationship between the two variables. Hirsch pointed out that the equation cannot be applied to myopias of less than 0.50 D. Emmetropia would, for example, according to this equation, be associated with a visual acuity of infinity (i. e., a zero threshold visual angle). Kempf, Collins and Jarman [28] reported a correlation ratio of 0.74 between diopters of refractive error and visual acuity. This was based on tests of more than 1,800 eyes whose visual acuity and refractive error were measured under homatropine

TABLE 2.—*Data from Previous Studies on Average Error of Refraction for Different Levels of Acuity (Subjects with Simple Myopia or Simple Hypermetropia)*

	Crawford and others [30]		Kempf and others [28]	
Acuity	Average Myopia, D.	No. of Subjects	Average Hypermetropia,* D.	No. of Subjects
20/20	0.32	40	0.41	270
20/30	0.50	36	0.58	208
20/40	0.66	76	0.85	191
20/50	0.82	69	0.99	107
20/60	0.97	44	....	...
20/70	1.30	11	1.16	140
20/80	1.33	6	....	...
20/100	1.87	7	1.56	172
20/200	2.06	19	2.31	25

* The acuities of the hypermetropic subjects were measured under cycloplegia.

TABLE 3.—*Data from Crawford and Associates, Showing Average Error of Refraction for Different Levels of Acuity*

	Subjects with Simple Myopic Astigmatism		Subjects with Compound Myopic Astigmatism	
Acuity	Average, D.	No. of Subjects	Average, D.*	No. of Subjects
20/20	0.34	41	0.66	50
20/30	0.67	30	0.82	94
20/40	0.90	50	0.96	181
20/50	1.14	22	1.16	114
20/60	1.08	9	1.36	108
20/70	1.35	5	1.72	39
20/80	....	0	1.83	18
20/100	1.83	3	2.00	21
20/200	....	0	2.18	34
20/400	....	0	3.42	55

* In meridian with higher error of refraction.

cycloplegia. The correlation ratio [29] for the 123 myopic eyes was 0.80 when acuity was tested under cycloplegia and 0.78 when tested without cycloplegia. Crawford, Shagass and Pashby,[30] in 1945, reported data on the acuities of 325 eyes with simple

28. Kempf, G. A.; Collins, S. D., and Jarman, B. L.: Refractive Errors in the Eyes of Children as Determined by Retinoscopic Examination with a Cycloplegic, Bulletin 182, United States Public Health Service, 1928.

29. Correlation ratios, rather than coefficients, were computed in this study because of the nonlinear relationship between visual acuity and refractive error.

30. Crawford, J. S.; Shagass, C., and Pashby, T. J.: Relationship Between Visual Acuity and Refractive Error in Myopia, Am. J. Ophth. **28**:1220 (Nov.) 1945.

myopia, 160 eyes with simple myopic astigmatism and 714 eyes with compound myopic astigmatism. The correlation ratios for prediction of visual acuity from amount of refractive error were for the three groups, respectively, 0.83, 0.79 and 0.76.

The high correlations reported in these three studies show that there is a fairly close relationship between visual acuity and diopters of uncorrected refractive error. Because of the greater number of eyes examined, the studies of Kempf [28] and Crawford [30] and their associates provide better data than those of Hirsch for determining the quantitative relationship between acuity and refractive error. Tables 2 and 3 present data derived from these studies. Table 2 gives for eyes with simple myopia or simple hypermetropia [31] the average error of refraction for each level of visual acuity. As a first approach to a determination of the form of the relationship between these two variables, the data of table 2, converted to logarithmic units, were

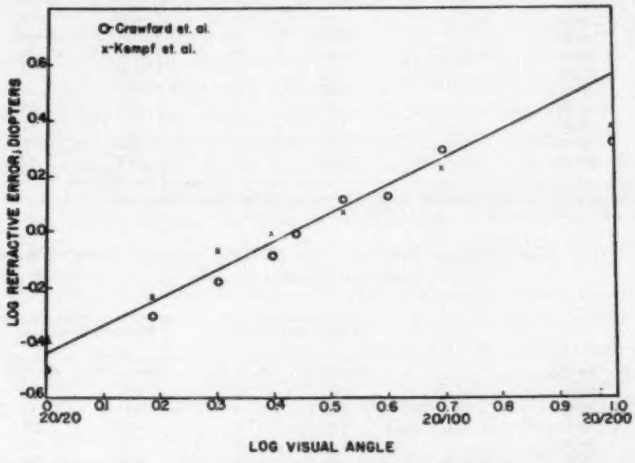

Fig. 2.—Relationship between threshold visual angle and diopters of spherical error of refraction. Data are from Kempf, Collins and Jarman [28] (circles) and from Crawford, Shagass and Pashby [30] (crosses). The equation of the straight line drawn through the experimentally determined points is $\log M = \log A - 0.44$, in which M is the refractive error in diopters and A is the threshold visual angle in minutes. This may be reduced to the simpler equation, $A = 2.80M$.

plotted on a graph (fig. 2). It may be seen that between the limits of 20/20 and 20/100 the experimental data of both studies fit closely the straight line whose equation is $\log M = \log A - 0.44$, in which M equals diopters of myopia or hypermetropia and A equals the minimum visual angle (reciprocal of the Snellen fraction). Since this equation can be reduced to the simpler form $M = 0.36A$, the data indicate that between the limits of 1 and 5 minutes the threshold visual angle is directly proportional to the amount of the refractive error. A more direct test of this relationship is provided by figure 3, in which the minimum visual angle is plotted on the

31. The uncorrected visual acuities of the hypermetropic subjects were determined under cycloplegia.

abscissa, the corresponding average refractive error on the ordinate. Again, it may be seen that for visual angles between 1 and 5 minutes (acuities between 20/20 and 20/100) the experimental points are close to the straight line defined by the equations $M = 0.36\ A$ or $A = 2.8\ M$. Figure 2 shows that for subjects with an acuity of 20/200 the average amount of myopia is less than that predicted from the equation. Since, however, the acuity charts employed in these two studies did not include any letter sizes between 20/100 (5 minutes) and 20/200 (10 minutes), the data do not provide accurate measures of threshold visual angles greater than 5 minutes. An adequate test to determine whether or not the same linear relationship between visual angle and diopters of myopia holds for acuities poorer than 20/100

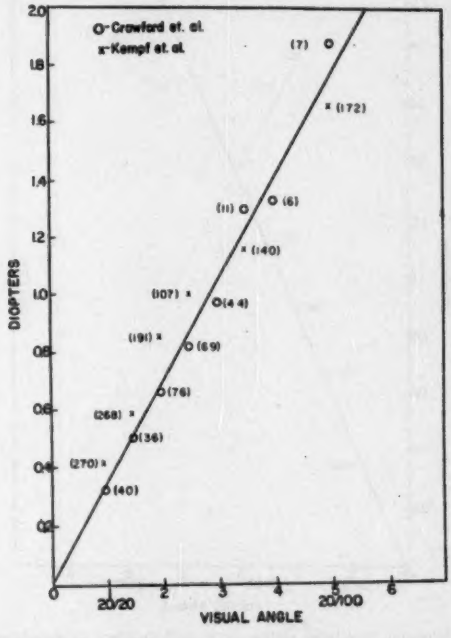

Fig. 3.—A replot of the data of figure 2 in arithmetical units. The straight line has the equation $A = 2.80M$. In figures 3 to 5 the numbers in parentheses give the number of eyes having each level of acuity.

requires additional studies, using finer measures of the threshold visual angle in this range. The equation cannot be extended to apply to acuities better than 20/20, because in this range the effect of refractive error on acuity is negligible and acuity is limited by the resolving power of the retina itself.

The study of Crawford and associates (table 3) also provides data giving, for 160 eyes, the average amounts of simple myopic astigmatism associated with different levels of visual acuity. Because only 17 subjects had acuities lower than 20/50 (minimum visual angle greater than 2.5 minutes), these data can only approximate the probable relationship between minimum visual angle and diopters of astig-

matism. Figure 4 shows that a straight line whose equation is $M = 0.45\,A$ or $A = 2.24\,M$ agrees closely with the experimental data for acuities between 20/20 and 20/50. The difference in the constant in the equations for spherical and astigmatic errors indicates that the increase in threshold visual angle produced by a simple astigmatism is about 80 per cent of that produced by the same amount of spherical error of refraction. If we make the assumption that in a compound myopic astigmatism the effects of sphere and cylinder are additive, we obtain the equation $A = 2.80\,S + 2.24\,C$ or $A = 2.80\ (S + 0.8\,C)$ where S is the power of the sphere, and C that of the cylinder.

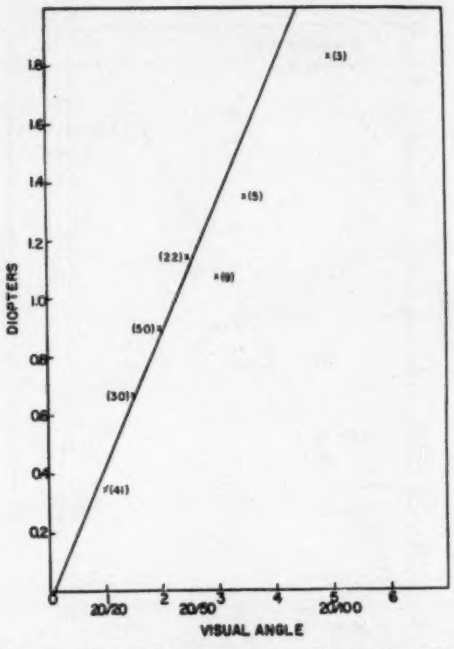

Fig. 4.—Relation between threshold visual angle and diopters of simple myopic astigmatism. The data are from Crawford, Shagass and Pashby.[30] The equation of the straight line is $A = 2.24M$.

Crawford's data for 714 eyes with compound myopic astigmatism (table 3) give only the sum of the spherical and cylindrical powers and so do not provide a direct check of this equation. The straight line which best fits the experimental points (fig. 5) has the equation $M - 0.3 = 0.355A$, or $A = 2.8\ (M - 0.3)$, where M equals the sum of the spherical and cylindrical errors. The equation may therefore be written $A = 2.8\ (S + C - 0.3)$. Whether this equation or the equation $A = 2.8\ (S + 0.8\,C)$ gives the better agreement with the experimental data cannot be determined, because Crawford gives only the values of $S + C$.

The findings of Crawford's study and that of Kemp and associates give strong support to the assumption that for uncorrected refractive errors of all types between

0.25 and 2.00 D., the minimum discriminable visual angle is directly proportional to the amount of refractive error when a suitable allowance is made for the smaller effect of astigmatic than of spherical errors. It appears, therefore, that the most generally useful gradation of test target sizes, in charts used to measure the impairment of acuity caused by uncorrected error of refraction, is one in which, for acuities of 20/20 and poorer, the denominators of the Snellen fraction increase by equal increments. If, for example, the Snellen notations are 20/20, 20/30, 20/40, 20/50, 20/60, etc., the visual angles subtended by the critical detail are 1.0, 1.5, 2.0, 2.5 minutes etc. The equation $A = 2.8\,M$ indicates that each increase in spherical

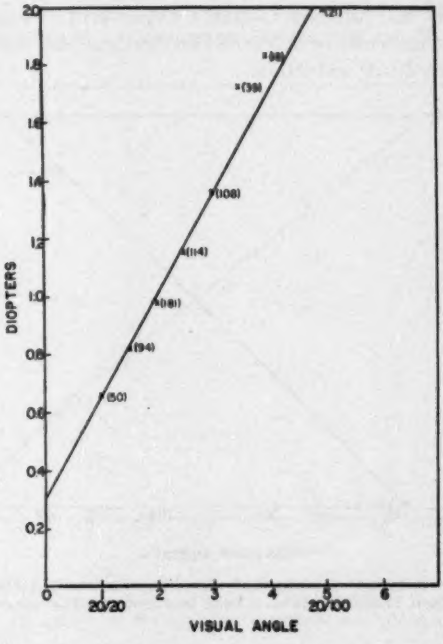

Fig. 5.—Relationship between threshold visual angle and refractive error for subjects having compound myopic astigmation (data from Crawford, Shagass and Pashby [30]). The refractive error is that of the meridian having the greatest defect. The equation of the straight line is $A = 2.8\ (M - 0.3)$.

myopia of 0.18 D. should reduce acuity by one line on the test chart. If a gradation is desired such that each increase of 0.25 D reduces acuity by one line, then the visual angles should increase by steps of 0.7 minute and the denominators of the Snellen fraction should increase by increments of 14,, i. e., 20/20, 20/34, 20/48, etc. If the same proportionate relationship between minimum visual angle and diopters of refractive error holds in the range between 5 and 10 minutes (20/100 and 20/200), it should be possible to measure, if desired, a number of significant differences in acuity between these limits. Because of the relatively large letters required,

however, such differences can be more feasibly measured by varying the distance between observer and test letters. For example, letters in which the critical detail subtends visual angles of 5, 6, 7, 8, 9 and 10 minutes may be obtained by viewing the same size of letter from distances of 20, 16.7, 14.3, 12.5, 11.1 and 10 feet.

The data on relationship between acuity and refractive error provide no information as to the best gradation of target sizes for measuring acuities of 20/20 and better. In this range differences in acuity may depend primarily on differences in retinal resolution. Commonly used charts distinguish only two levels of acuity better than 20/20. If finer differentiation in this range is desired, the sizes of test letter might vary, for example, by equal steps on a visual angle scale, a visual acuity scale (reciprocal of visual angle) or a logarithmic scale. The studies of visual acuity conducted by the Adjutant General's Department [101] suggest that charts scaled in logarithmic units may be best suited for distinguishing differences in acuity in the range between 20/20 and 20/10.

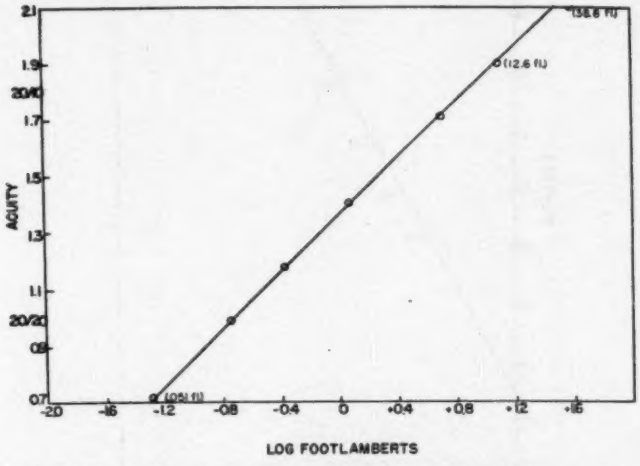

Fig. 6.—Data from Lythgoe,[32] showing the relationship between luminance of background and visual acuity for dark Landolt rings on a light background. The equation of the straight line is $V = 0.5 \log L + 1.35$.

EFFECTS OF ILLUMINATION AND CONTRAST ON VISUAL ACUITY

It is obvious that ability to discriminate critical detail in a given test object must vary with two photometric quantities, namely, the amount of light reflected or transmitted by the test object and the amount reflected or transmitted by the background against which the test object is viewed. The brightness sensitivity of the eye is the major determining factor when the test object is large and there is only a small difference between luminance of test object and background. When, on the other hand, the test object is small and the difference in luminance is great, acuity is the primary factor. In the commonly used test charts for the measurement of visual acuity, "black" letters or other test objects reflecting about 5 per cent of the incident illumination are viewed against a "white" background reflecting about 80 per cent. For convenience, it is customary to specify independently (*a*) the luminance of the

white background, i. e., the incident illumination times the reflection of the background, and (*b*) the contrast between the test object and background, i. e., the difference in reflectance divided by the reflectance of the background. Thus, for commonly used acuity charts in which the "black" test targets reflect about 5 per cent of the incident light and the "white" background reflects about 80 per cent, the luminance of the background, in foot-lamberts, is 0.80 times the illumination, in foot-candles, and the contrast is $\frac{0.80 - 0.05}{0.80}$, or 0.94.

Variation of Acuity with Luminance of Background.—The general trend of this relationship has been confirmed in many investigations, all of which show that within a middle range of luminances acuity is directly proportional to the logarithm of the luminance, when the contrast between test object and background remains constant. Typical results for luminances between 0.05 and 39 foot-lamberts, taken

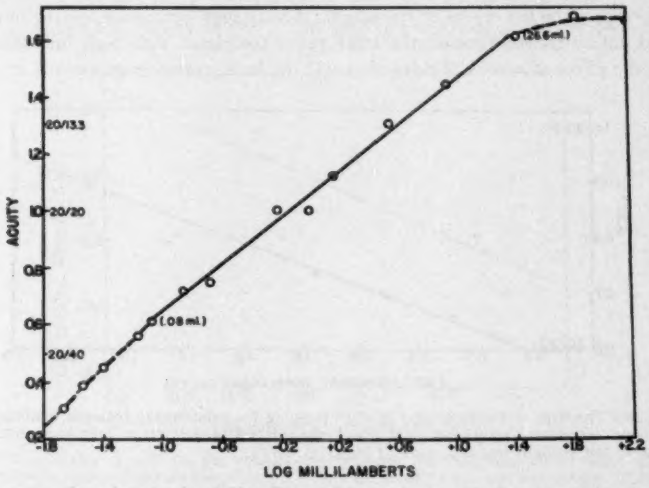

Fig. 7.—Koenig's data, recomputed by Hecht,[33] showing the relationship between luminance of background and visual acuity for dark Snellen hooks on a light background. For values of log L between -1.0 and $+1.4$, the data fit the straight line whose equation is $V = 0.4 \log L + 105$.

from Lythgoe's study,[32] are shown in figure 6. The experimental data fit the equation $V = 0.5 \log I + 1.35$, in which V equals visual acuity and I equals luminance of the background in foot-lamberts. The Landolt ring was used as the test target in these studies. The data of Koenig, obtained with the Snellen Hook, agree closely with those of Lythgoe. Between luminances of 0.1 and 27 millilamberts, Koenig's data, as recomputed by Hecht,[33] fit the equation $V = 0.4 \log I + 1.05$ (fig. 7). Above 27 millilamberts acuity increases somewhat more slowly with

32. Lythgoe, R. J.: The Measurement of Visual Acuity, Medical Research Council, Special Report No. 173, London, His Majesty's Stationery Office, 1932.

33. Hecht, S.: Relation Between Visual Acuity and Illumination, J. Gen. Physiol. **11**:255, (Jan.) 1928.

increase in luminance. Feinberg and Wirt,[34] using the Ortho-Rater checkerboard target, again found a linear relationship between acuity and the logarithm of the luminance of the background. Their data, however, show a slower increase in acuity with increase in luminance (fig. 8). The equation of the best fitting straight line is $V = 0.19 \log I + C$, in which I is expressed in arbitrary units.

In the measurement of individual differences in acuity, it is obvious that some standard luminance of background must be adopted. Lythgoe's data show that if the luminance is maintained constant within ± 25 per cent the variation in acuity with luminance will be only ± 0.05. The level of luminance adopted as standard should approximate that encountered in the use of the eyes under ordinary conditions, in which acuity is determined primarily or entirely by the response of the foveal cones. A very low luminance will not satisfy this requirement, because the results may depend in part on the response of the rod mechanism and because the widely dilated pupil associated with low luminance exaggerates the effect on acuity of uncorrected errors of refraction. A very high luminance, on the other hand, should not be chosen because the small pupil associated with high luminance minimizes the effect of errors of refraction. If the background brightness is maintained

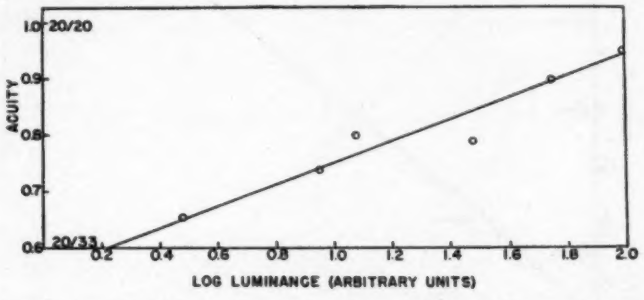

Fig. 8.—The data of Feinberg and Wirt,[34] showing the relationship between luminance of the background and visual acuity for dark checkerboard test targets on a light background. The equation of the straight line is $V = 0.19 \log L + C$.

constant within the limits of about 12 to 18 millilamberts, the above mentioned requirements are adequately fulfilled.

Variation of Acuity with Contrast.—Cobb and Moss [35] investigated the change in acuity with change in contrast from 1 to 97.9 per cent. The test object was a dark pair of parallel bars on a light background the luminance of which was kept approximately constant at 20 millilamberts (18.6 foot-lamberts). The mean data of nine observers fit the equation $\log (C - 1.28) = 1.46 - 1.4 \log (A - 0.56)$ or $\log (A - 0.56) = 1.04 - 0.715 \log (C - 1.28)$, where C is the per cent contrast and A, the minimum discriminable visual angle in minutes. As would be expected, the equation shows that acuity approaches a finite limit as contrast becomes maximal, and discrimination of brightness contrast likewise approaches a finite limit when the test object becomes very large.

34. Feinberg, R., and Wirt, S. E.: Visual Acuity in Relation to Illumination in the Ortho-Rater, J. Appl. Psychol. **31**:406, 1947.

35. Cobb, P. W., and Moss, F. K.: Relation Between Extent and Contrast in Liminal Stimulus for Vision, J. Exper. Psychol. **10**:350 (Aug.) 1927.

Ludvigh [36] made a similar study, using Snellen letters of varying reflectances on a background whose luminance was kept constant at about 12 millilamberts (11 foot-lamberts). His data (fig. 9) can be fitted to an equation of the form proposed by Cobb and Moss, with different constants, namely, $\log (C - 5) = -4.55 \log (A - 0.2) - 0.32$, or $\log (A - 0.2) = 0.22 \log (C - 5) - 0.07$.

The most important difference in the equations which fit the two sets of data is that Cobb and Moss find a more rapid increase in threshold visual angle with decrease in contrast. Both studies, however, show that at relatively high levels of contrast moderate changes have a negligible effect on acuity. If, for example, the reflectance of the dark test target does not exceed 10 per cent and that of the light background is not less than 65 per cent, the minimum contrast is $\frac{65 - 10}{65}$, or 84.6 per cent. If the lowest reflectance of the test target is 3 per cent, and the highest reflectance of the background 85 per cent, the maximum contrast is 96.5 per cent. The equation which fits the Cobb and Moss data shows that a contrast of 84 per cent corresponds to an acuity of 0.972 (20/20.6); a contrast of 97 per cent, to an

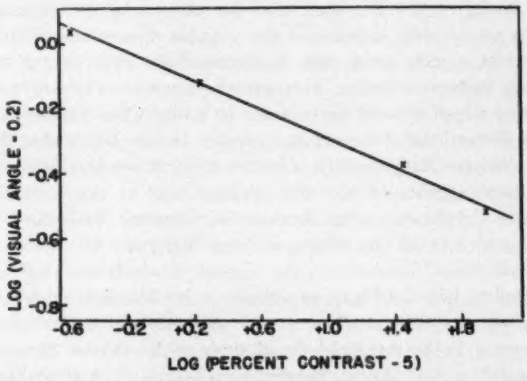

Fig. 9.—Ludvigh's data [36] on the relationship between the threshold visual angle and the per cent contrast, recomputed to show that they can be fitted to an equation similar in form to that proposed by Cobb and Moss.[35] See text.

acuity of 1.013 (20/19.7). For Snellen letters, Ludvigh's data show an even smaller change in acuity.

It may be concluded, therefore, that in the adoption of standard conditions for the testing of visual acuity, if the contrast is at least 84 per cent and if the background luminance is between 12 and 18 foot-lamberts, variations in contrast and in luminance of background will have a negligible effect on acuity.

EFFECT OF DISTANCE OF TEST OBJECTS ON ACUITY

Measurement of acuity in terms of the minimum visual angle which can be discriminated assumes implicitly that acuity (reciprocal of threshold visual angle) does not change significantly with change in the distance at which the determinations are made, provided that the retinal image of the test object remains accurately

36. Ludvigh, E.: Effect of Reduced Contrast on Visual Acuity as Measured with Snellen Test Letters, Arch. Ophth. **25**:469, (March) 1941.

focused. This assumption has been questioned by a number of investigators, who found a consistent change in acuity with distance of test object under conditions in which the variable effects of uncorrected myopia, presbyopia, etc., on the clearness of the retinal image were ruled out. Beebe-Center and his colleagues [37] in 1945 reviewed the previous investigations and stressed the contradictory nature of the findings evidenced by the fact that some reported an increase in acuity with increase in distance, others a decrease. Because such factors as improvement with practice, illumination and angular extent of the background were, in many cases, not adequately controlled, these authors considered that the previous studies do not provide any conclusive answer. Their own experiments at distances of about 30 feet and 2 miles showed only a 7 per cent change in acuity with this very great change in distance. Dimmick and Rudolph [38] likewise found no significant effect of distance on acuity for distances between 2 and 21 meters. Musylev [39] found for five observers that acuity was the same when measured at 2.8 and at 14 meters, provided the angular extent of the background was the same at both distances. In other experiments he demonstrated that acuity, measured at a constant distance, varies with the extent of the background. For dark test objects on a light background, there was an increase in acuity with increase in the angular dimensions of the background; and for light test objects on a dark background the reverse was true. Lack of control of this factor could therefore explain the contradictory results of other studies, some of which showed an increase in acuity with distance, others just the reverse. For distances of 2 meters and greater, it seems probable that under adequately controlled conditions acuity is practically independent of distance. On the other hand, there appears to be valid evidence that at relatively short distances acuity decreases significantly with decrease in distance. Freeman [40] reported data showing that acuity at 30 cm. is less than at 300 cm. His tests were all made at very low background luminances, the highest of which was only about 1 microlambert. Musylev, who used a more representative illumination level of 400 meter candles, found for one subject whose acuity was measured at 100 and at 35 cm. an 8 per cent increase in the threshold visual angle at the shorter distance. Two subjects tested at 100 and at 20 cm. showed increases of 17 and 65 per cent, respectively, in the threshold at the shorter distance. Since an artificial pupil was employed both by Musylev and by Freeman, the decrease in acuity cannot be attributed to a change in size of pupil.

Giese [41] found that the mean visual acuity of 400 subjects decreased regularly and significantly with decrease in distance from 1 meter to 20 cm. At 1 meter,

37. Beebe-Center, J. B.; Mead, L. C.; Wagoner, K. S., and Hoffman, A. C.: Visual Acuity and Distance of Observation, J. Exper. Psychol. **35**:473, 1945.

38. Dimmick, F., and Rudolph, L.: Checkerboard Visual Acuity Targets: An Experimental Validation, Bureau of Medical Research, Project NM-003-008 (X-423), Report No. 1, December, 1948, United States Naval Medical Research Laboratory, United States Naval Submarine Base, New London, Conn.

39. Musylev, F. I.: Die Abhängigkeit der Sehschärfe von der Entfernung des Objektes, Acta ophth. **15**:216, 1937.

40. Freeman, E.: Accommodation, Pupillary Width and Stimulus Distance, J. Optic. Soc. America **22**:729 (Dec.) 1932; Intensity, Area, and Distance of Visual Stimulus, ibid. **22**:402 (July) 1932; Anomalies of Visual Acuity in Relation to Stimulus-Distance, ibid. **22**:285, (May) 1932.

41. Giese, W. J.: The Interrelationship of Visual Acuity at Different Distances, J. Appl. Psychol. **30**:91, 1946.

for example, the mean acuity was 1.63 (20/12.3); at 40 cm., 1.37 (20/14.6); at 20 cm., 0.95 (20/22.3). Errors of refraction were not corrected, but all the subjects had at least 20/20 vision at the standard distance of 20 feet (6 m.). The median age was 19 years, and no subject was over 36. Since only older subjects with high hypermetropias would be unable to accommodate for the shorter distances, it seems unlikely that the observed decrease in acuity could be attributed to insufficient power of accommodation for the nearer distances.

While it is probable, therefore, that there is some factor which reduces acuity at short distances less than 1 meter, further investigation is needed to determine the cause of the phenomenon. It is possible that the eye does not focus as accurately for close objects even when they are well beyond the near point of accommodation. Musylev suggested that the associated convergence of the eyes at short distances might in some way impair visual acuity. It is also possible that the phenomenon is an artefact associated with poor reproduction of the very small test objects required at the shorter distances. If it is a real phenomenon, further studies are needed to determine more precisely the magnitude of the decrease in acuity and how much it varies in different subjects.

Significant differences in acuity measured at different distances can, of course, occur in subjects with uncorrected errors of refraction. The subject with uncorrected myopia will show a gradual increase in acuity with decrease in distance from 6 meters up to his far point. Any subject will show a decrease in acuity when the test object is brought within his near point. The subject with uncorrected presbyopia, for example, whose near point is at 50 cm., will show a reduction in acuity at shorter distances. The subject with corrected presbyopia will have reduced acuity in the intermediate range of distances which are within his near point when he looks through the distance portion of his glasses and beyond his far point when he looks through the reading portion.

Acuity measured at 6 meters, nevertheless, provides a valid index of acuity at all greater distances, even though there is an uncorrected error of refraction, since there is no significant change in the blurring of the retinal image with further increase in the distance of the test object. Measures of acuity at 6 meters, however, cannot be expected to correlate highly with measures at a shorter distance if the subjects tested have uncorrected or only partially corrected errors of refraction. In industry, where the employee may be presbyopic, and may or may not have glasses which adequately correct his refractive error, screening tests are given to determine whether he nevertheless has adequate vision for his particular job. To answer this question it may be necessary to test acuity not only at 6 meters but also at some shorter distance suitably chosen in relation to the demands of his job. The military services also set qualifying standards for many assignments which require a certain minimum level of uncorrected visual acuity. When the subjects are below the age at which presbyopia occurs, tests at 6 meters and at 40 cm. provide an adequate basis for prediction of performance at all other working distances.

Another problem relating to the effect on acuity of distance of test target is presented by testing devices, such as the Ortho-Rater, the Sight-Screener and the Telebinocular. In these the test letters are only about 40 cm. from the subject, but, because of the convex lenses and prisms placed before his eyes, the accommodation and convergence required for clear vision are the same as though the target were at

a distance of about 6 meters. A possible objection to these instruments is that since the subject knows that the test target is actually only a short distance away, he may accommodate, not for its optical distance, but for some nearer distance. If such "apparatus accommodation" occurs, the acuity will be lower than when measured in the usual way.

There has been only one attempt to determine experimentally whether or not there are significant differences in acuity for test objects at true and at simulated distance. Cook [42] compared acuities measured on the Ortho-Rater and the Sight-Screener with measures at 20 feet, using suitably enlarged reproductions of the test targets of each instrument. On the Ortho-Rater the mean acuity of 256 eyes was higher at a simulated distance of 26 feet than at a true distance of 20 feet. On the Sight-Screener acuity was lower at simulated than at true distance. Since there is no evidence that the tests were made under otherwise identical conditions, for example, with the same background luminance, the same contrast between test object and background, etc., and since the photographic reproduction of the targets used at 20 feet was poor, particularly in the case of the Ortho-Rater, no final conclusions can be drawn from this study, and further investigation is needed to determine whether or not "apparatus accommodation" causes a significant decrease in acuity in tests in which distance is simulated optically.

MEASURES OF THE COOPERATION OF THE TWO EYES IN BINOCULAR VISION

The procedure commonly used to determine the visual acuity of each eye is to cover the nontested eye with an occluder. For special purposes it may be desirable to make such determinations by a method which presents to the nontested eye an image which is partially similar to that of the tested eye, so that the stimuli for convergence and accommodation are similar to those of binocular vision. Haploscopic instruments, such as the Bausch & Lomb Ortho-Rater, provide for measures of acuity of each eye either with or without occlusion of the other. In many cases the acuity is higher with occlusion than without. If, for example, the right and left eyes have, respectively, 1.50 and 0.50 D. of uncorrected hypermetropia, each eye may nevertheless obtain normal acuity when the other is occluded, by exerting sufficient accommodation to correct for its hypermetropia. Since the two eyes cannot accommodate unequally, in binocular vision the amount of accommodation will probably be that required by the dominant eye. When the acuity of each eye is tested without occlusion of the other, the observed acuity may therefore be lower than with occlusion, particularly in the nondominant eye. Even when there is no uncorrected spherical anisometropia, the acuity of the nondominant eye will be reduced if there is any suppression of its image in binocular vision. Important supplementary information as to the "functional" acuity of each eye in binocular vision is therefore provided by this method of measuring acuity. This or some other means [43] of comparing the acuities of the two eyes in binocular vision is

42. Cook, E. B.: Comparative Performance of Commercial Screening Devices and Far and Near Wall Charts Utilizing the Same Visual Test Targets, Bureau of Medical Research, Project NM-003-011 (X-493), Report No. 5, August, 1948, United States Naval Medical Research Laboratory, United States Naval Submarine Base, New London, Conn.

43. Comberg, W.: Über relative binokulare Korrektion, Arch. Augenh. **87**:75, 1921. van Wien, S.: Leland Refractor: Method for Refraction Under Binocular Conditions, Arch. Ophth. **23**:104 (Jan.) 1940. Luckeish, M., and Moss, F. K.: Comparison of New Sensitometric Method with Usual Technics of Refraction, ibid. **30**:489 (Oct.) 1943.

useful to the ophthalmologist or optometrist in the selection of a refractive correction which will require for maximal acuity the same accommodation in each eye. If the patient's occupation requires a high degree of binocular depth perception, it is particularly important that the refractive corrections of the two eyes be balanced. In selection tests, on the other hand, such as are required in industry and in the military services, for example, a reliable test of depth perception perhaps provides the most direct measure of the efficiency of binocular vision. If an adequate test of depth perception is available, it is not necessary that the tests of monocular acuity be supplemented by tests of the functional acuity of each eye in binocular vision, since any significant impairment will result in an impairment of binocular depth perception.

SUMMARY AND CONCLUSIONS

The information from previous studies reviewed in this paper leads to certain conclusions regarding the specifications for an acuity test suitable for screening and for classification.

1. Until something better is developed, familiar nonserif letters selected to be approximately equal in legibility are perhaps the best available type of test target for literate subjects. Suitably chosen letters are sufficiently complex in form to test acuity in all meridians simultaneously and therefore should not lead to overestimating the acuity of subjects with uncorrected errors of refraction in one meridian only.

2. If the contrast between dark test object and light background is not less than 84 per cent, variations in acuity with changes in contrast will not be of significant amount. A brightness of 12 to 18 millilamberts is recommended as most representative of conditions under which the eyes are ordinarily used. Variations in the brightness of the background of $\pm$ 25 per cent or less have a negligible effect on acuity.

3. Measures of acuity for purposes of screening and classification should be made at a distance of about 6 meters, and in special cases at one or more nearer distances representative of typical working conditions.

4. The visual acuity of each eye should be determined with occlusion of the other eye. Supplementary tests, such as tests of depth perception, may be used to evaluate the efficiency of binocular vision.

Areas in which further investigation is particularly indicated are as follows:

1. The question of the ideal type of test target needs further study.

2. Because of the many conveniences of testing acuity at simulated rather than at true distance, an adequate investigation of the validity of this procedure is needed.

3. Visual acuity charts whose gradations between about 20/20 and 20/100 are in equal steps on a visual angle scale should be tested in order to verify the indications of previous studies that with such gradation the intervals correspond to equal dioptric differences in error of refraction.

4. Further investigation is needed to determine the most suitable gradation of target sizes smaller than 20/20 and larger than 20/100.

Society Transactions

EDITED BY DR. W. L. BENEDICT

NEW YORK ACADEMY OF MEDICINE, SECTION OF OPHTHALMOLOGY

R. Townley Paton, M.D., *Chairman*

Raymond L. Pfeiffer, M.D., *Secretary*

Regular Meeting, March 19, 1951

Viral Infections of the Eye. DR. PHILLIPS THYGESON (by invitation).

In 1943 the author reviewed the literature on viruses as related to ocular diseases before this society (Virus and Virus Diseases of the Eye, ARCH. OPHTH. **29:** 285 [Feb.]; 488 [March] 1943). The present report summarizes the advances made in this field since 1942.

The most important advances have been concerned with the recognition of new viral diseases of the eye, e. g., Newcastle disease conjunctivitis, and with the demonstration of the viral etiology of other diseases, e. g., superficial punctate keratitis. Progress in the chemotherapy of viral diseases, although important, was limited to the psittacosis-lymphogranuloma venereum group, in which broad spectrum antibiotics, such as aureomycin, chloramphenicol (chloromycetin®) and terramycin, were shown to be extraordinarily effective. With the possible exception of herpes zoster and herpes simplex viruses, no others have as yet been found responsive to chemotherapy. Of special interest has been the recognition of the widespread distribution of herpes simplex virus infection in the general population, the primary infection occurring ordinarily in childhood as an aphthous stomatitis, with persistence of the virus throughout life. The ocular infection usually occurs as a secondary manifestation, in the form of dendritic keratitis, but may occasionally be primary, when it appears as a severe keratoconjunctivitis, sometimes with pseudomembrane formation.

The general failure of cortisone to produce improvement in ocular infections of viral origin has been noted. In experimental vaccinia virus keratitis and herpes simplex virus keratitis, on the other hand, cortisone produced an increase in the severity of the ocular lesion and greatly increased the incidence of encephalitis.

Advances in the diagnosis of viral diseases of the eye included (1) the use of the phase microscope for the rapid recognition of inclusion bodies, (2) improved staining of elementary bodies, (3) recognition of a mononuclear exudate as a characteristic of viral infection of the conjunctiva and cornea, (4) introduction of a skin test for herpes simplex virus infections and (5) improvement in serologic technics for the recognition of antibodies produced by viruses.

News and Notes

EDITED BY DR. W. L. BENEDICT

UNIVERSITY NEWS

Course in Ophthalmic Pathology, Washington University School of Medicine.—The Department of Ophthalmology, Washington University School of Medicine, St. Louis, announces an intensive course in the pathology of the eye and adnexa, to be given by Dr. T. E. Sanders. This course will be of one week's duration, from Sept. 10 through Sept. 15, 1951, and will total about 40 hours, including both didactic and microscopic work. The course is limited to 10 students. The tuition fee is $125. Those interested may communicate with the Department of Ophthalmology, Washington University School of Medicine, 640 South Kingshighway Boulevard, St. Louis 10.

GENERAL NEWS

International Congress of Ophthalmology.—At a meeting of the International Council of Ophthalmology, in Paris, on May 5, 1951, it was voted to hold the next International Congress of Ophthalmology in New York in the autumn of 1954.

Book Reviews

Augen ärztliche Eingriffe. By J. Meller. Sixth edition, revised by J. Böck. Price not stated. Pp. 494, with 281 illustrations. Springer-Verlag, Mölkerbastei 5, Vienna, 1, 1950.

In the short preface to the sixth edition of this masterly book, J. Meller mentions that the previous edition of 1946 went out of print in less than a year. If confirmation of the great appeal of this book to eye surgeons were necessary, it would be clearly shown by this unusual demand.

The qualities of the text, which is one of the best teaching aids in ophthalmology ever written, will be remembered by all who had contact with the previous editions. This concise presentation of surgical procedures on the eye and its adnexa contains all essentials for the young ophthalmologist. Clear language, comprehensive organization and a logical selection of material again characterize the new edition, which is a revision by Meller's pupil Josef Böck. He wisely did not alter essentially many of the chapters based on the experience of the great surgeon, teacher and master of the German language. There are several supplementary paragraphs in many of the chapters in this edition, however, written with the purpose of keeping astride with advances in ocular surgery which have occurred in the last years. The main addition is a short chapter on corneal transplantation. Despite limited space (11 pages), it contains a great deal of useful information. Improvement over the previous edition was further accomplished by replacing some illustrations and including others which are instructive because of the details they show.

Thus, in view of these mentioned qualities, the book fills an important need for those who have no access to large libraries. There can be little doubt that the high standards of this enlarged edition will find full recognition by members of the medical profession and will serve in an excellent manner the practical needs of the ophthalmic surgeon.

Eye Manifestations of Internal Diseases; Medical Ophthalmology. By I. S. Tassman, M.D. Third edition. Price, $12. Pp. 672, with 279 illustrations, 25 in color. C. V. Mosby Company, 3207 Washington Blvd., St. Louis 3, 1951.

This book has grown in both quantity and quality through the three editions which have been printed. Considerable new material has been included, such as retrolental fibroplasia, Harada's disease, Bechet's syndrome, the effects of rubella in pregnancy, acute anterior poliomyelitis, the Sturge-Weber and Sjögren syndromes, malignant exophthalmos and scrub typhus. Treatment has been brought up-to-date, with the inclusion of the more modern antibiotics.

As this is a monograph on medical ophthalmology, it is hoped that the author will eliminate chapters which are somewhat irrelevant. The chapters on the normal structure of the eye and orbit and the examination of the patient could well be omitted, as they are found in all textbooks of ophthalmology. This would save 53 pages. In addition, those local conditions of the eye which have no known relation to general conditions of the body could be omitted.

There is a great need for an authoritative text on medical ophthalmology, and while the reviewer believes that this is the best text available in English at present, it could be considerably improved in future editions. Most of the illustrations are good, but there are many that leave much to be desired. The omission of these would improve the book.

The general arrangement of this edition does not differ from the previous ones.

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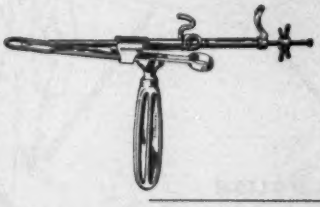

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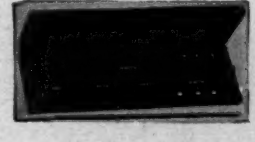

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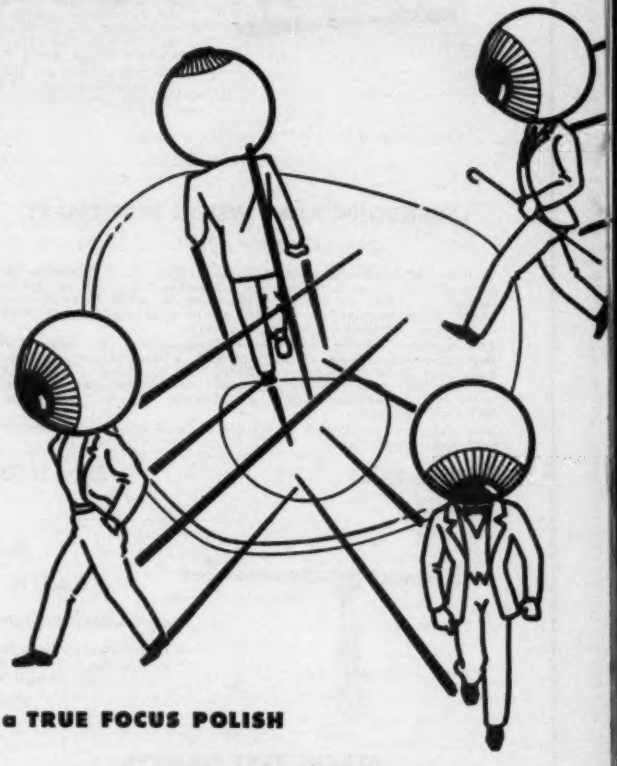

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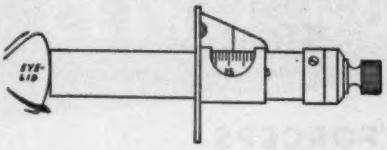

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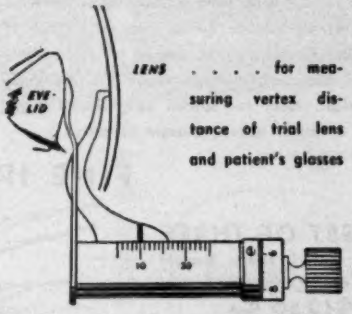

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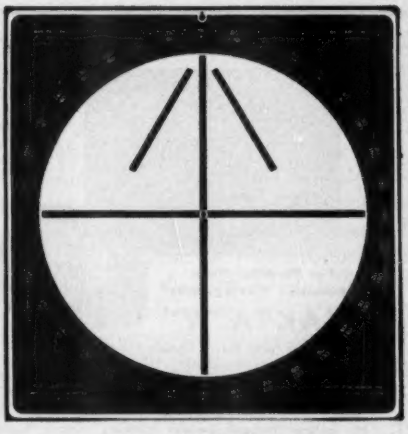

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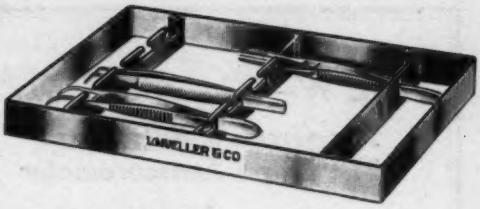

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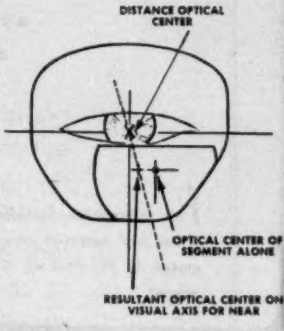

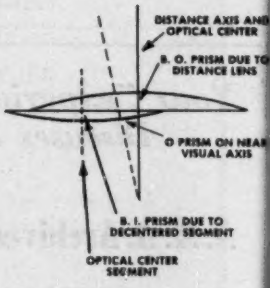
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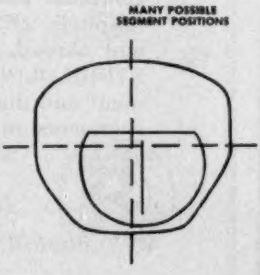

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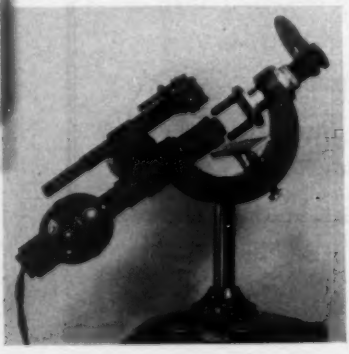

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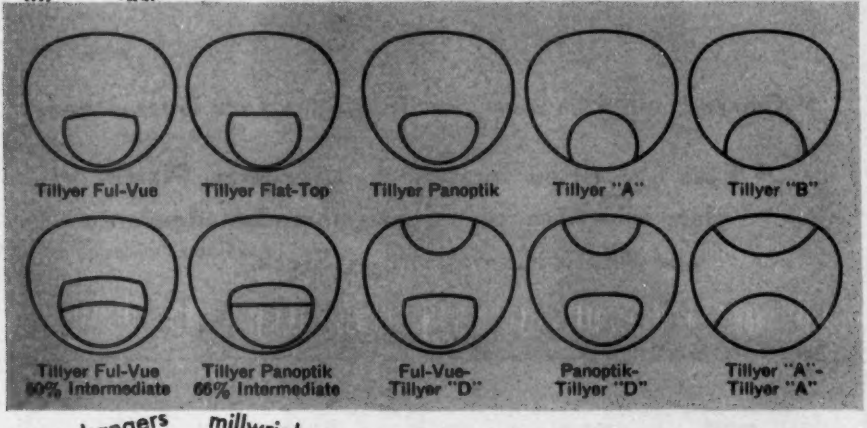

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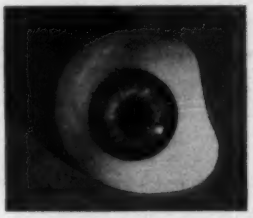

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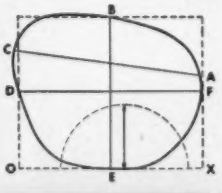

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40	41 x 34	40 x 34	18-20-22
42	43 x 36	42 x 36	18-20-22-24
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